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HISTORY

The first reference to the introduction of the avocado into California found thus far is made in the Report of the Visiting Committee of the California State Agricultural Society in 1856. According to this report, Dr. Thomas J. White, living near Los Angeles, had imported the avocado from Nicaragua along with other tropical fruit plants. It was not until some years later, however, that the avocado became definitely established through the introduction of three trees from Mexico in 1871 by Judge R. B. Ord of Santa Barbara. Two of the three trees of his importation bore fruit for many years in Santa Barbara and served to create interest in further plantings.

California has been fortunate in having had among her early settlers persons who have taken a keen interest in horticulture, especially that phase of it dealing with subtropical plants—fruit-bearing and ornamental. The early history of the avocado in this state is particularly marked by such effort. In the years following the introduction by Judge Ord, many trees were planted, some being imported from Mexico and the countries of Central America, others being started from the seeds of the many fruits that had found their way into California, brought here by travelers. Among the many pioneers who contributed to the impetus given avocado growing were J. C. Harvey and Jacob Miller of Los Angeles, and Dr. F. Franceschi (Fenzi), formerly of Santa Barbara.

In the early nineties Juan Murrieta of Los Angeles became interested in the avocado through Mr. Harvey, and imported a considerable quantity of thick-skinned fruit from Atlixco, Mexico. Some seeds from these he distributed among his friends and others he planted. From this group of seedling trees have come a number of the varieties

[1] This publication represents a complete revision of California Agricultural Experiment Station Bulletin 365, Avocado Culture in California; Part I, History, Culture, Varieties, and Marketing, by Knowles Ryerson; Part II, Composition and Food Value, by M. E. Jaffa and H. Goss. It was originally issued in 1923, revised by R. W. Hodgson and reissued in 1928.

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that first attracted attention as promising commercial fruits. These include the Royal, Walker, Challenge, Dickey, Blakeman, Sharpless, Colorado, and Murrieta. C. P. Taft of Orange, in 1899 and the years immediately following, also planted many seeds from various sources. These early plantings stimulated interest in the commercial possibilities of the avocado, and numerous experimental plantings were made in the first decade of the present century.

The period since 1910 has been marked by special emphasis on the commercial aspects of avocado culture (fig. 1). In place of relying on chance seedlings, nurserymen undertook the exploration of the avocado districts of Mexico and Guatemala. F. O. Popenoe and T. U. Barber of the West India Gardens, Altadena, were pioneers in this field, and during 1911–1912 brought in budwood of many varieties found in the best districts of Mexico. Of these the Fuerte and Puebla have since proved to be of especial merit. E. E. Knight of Yorba Linda, a resident for many years of Central America, also brought in budwood of superior varieties from Guatemala, of which the Queen and Linda have proved to be the most promising.

Joseph Sexton of Goleta introduced selected seeds and buds from the best West Indian varieties grown in the Hawaiian Islands. The failure of his plantings, under favorable climatic conditions, early indicated the futility of planting varieties of this race.

Realizing that private endeavor could hardly be expected to thoroughly explore the avocado districts of foreign countries, and that it was desirable to provide the young industry with the advantage of the best varieties available as a foundation, the Office of Foreign Plant Introduction of the United States Department of Agriculture undertook the exploration of all avocado districts in Mexico and Central and South America. For the better part of nine years Dr. Wilson Popenoe, as an agricultural explorer, combed these regions, with the result that the avocado growers of California and Florida now have the best that the world affords in the way of varieties upon which to build a commercial industry. Probably no other horticultural industry has had a similar advantage in its infancy. These introductions have now been under test for some years, and a number of them are showing decided promise. It will require several years more, however, before their value and adaptation to conditions in this state will be fully determined.

The work of the California Avocado Association, which was organized in 1915, has been one of the most important factors in the rapid development of avocado culture in this state. Its Committee on Registration and Classification of Varieties has rendered notable

service in studying varieties and recommending those suitable for commercial planting; its present list of a few standard varieties is an indication of the careful work which has characterized its activities. The published proceedings of this organization form the most valuable contribution to avocado literature available at the present time.

Fostered by the Association, a cooperating marketing agency known as the California Avocado Growers' Exchange was formed in 1924 and thus far has functioned successfully in marketing the rapidly increasing crop. In 1927 the name was changed to Calavo Growers of California.



Fig. 1.—Typical young bearing avocado orchard in southern California. (From Bul. 365.)

BOTANICAL DESCRIPTIONS AND RELATIONS

The avocado belongs to the genus *Persea,* a member of the Laurel family, to which belong also such economic plants as camphor, sassafras, and cinnamon. The common native California bay tree is likewise a member of this family. The cultivated species of the genus are native to Mexico and Central and South America. Early classification of avocados cultivated in the United States placed all in one genus, *Persea americana* Mill. (*P. gratissima* Gaertn.). More recent

studies have resulted in the making of two distinct species, *P. americana* and *P. drymifolia;* the former includes all varieties horticulturally grouped in the West Indian and Guatemalan races; the latter includes the small-fruited varieties of the Mexican highlands, of which many are grown in California, and which have also spread to Ecuador and Chile, and to a limited extent to the regions bordering the Mediterranean. These are grouped into the so-called Mexican race.

Persea drymifolia can be distinguished from *P. americana* by the very pronounced anise odor that can be detected in the leaves and young growth of the former when crushed; this odor is entirely lacking in *P. americana.* The flowers of *P. drymifolia* are regularly more pubescent than those of *P. americana* and the under surface of the leaves more glaucous. The fruits of *P. drymifolia* are characterized by a thin, membranous skin, differentiating them markedly from those of *P. americana,* which have a thick skin varying from a leathery to a brittle texture. The fruits of the latter species are usually much larger than those of the former. Both species are represented in the cultivated avocados of California.

The tree is evergreen, though in certain varieties practically all of the leaves drop for a brief period during the flowering season. The leaf blades are of many different shapes—oval, ovate, obovate, lanceolate, elliptic; and combinations of these appear. The leaf base is usually acute or truncate, the apex varies from almost blunt to acuminate. In length the leaves vary from 3 to 15 inches. The color of the mature foliage is usually bright green; the young growth, however, often exhibits varying shades of red and bronze. The manner of tree growth is variable; the tall, upright, unbranched habit and the short, well-shaped, spreading habit are both commonly found. Seedling trees attaining an extreme height of from 50 to 60 feet have been noted where soil conditions are particularly favorable (fig. 2). Budding apparently has a dwarfing effect. The resulting trees are more compact and spreading, and seemingly not inclined to grow as high as seedlings. None are of sufficient age, however, to settle this point definitely.

The small, pale, green or yellowish flowers are borne in terminal racemes. They possess both stamens and pistil. Differentiation between calyx and corolla does not occur in the avocado blossom. The petal-like structures are in reality perianth lobes, of about equal length, the inner series sometimes being longer than the outer. They are pubescent, pronouncedly so in *Persea drymifolia* and sometimes almost glaucous in *P. americana.* The nine stamens are arranged in three series; the anthers are four-celled, the cells opening by valves hinged at the upper end. At the base of each stamen of the inner series are two large, orange-colored glands which secrete nectar, presumably for the attraction of insects. Inside the stamens are three staminodia. The ovary is one-celled, and contains a single ovule. The style is slender, usually hairy, with a simple stigma. The flowers appear from November to May in California, varying according to variety and locality.



Fig. 2.—Old seedling avocado tree, indicating the height to which such trees grow in southern California. Note also the lath screen for wind protection. (From Bul. 365.)

The fruits of the cultivated species are extremely variable in size, shape, color, and other characters. Fruits of *Persea drymifolia* are found that are no larger than good-sized olives, while the largest varieties of *P. americana* weigh over three pounds. In shape they may be round, oval, pyriform, 'bottle necked,' or any of the numerous gradations between these forms. The color ranges from light yellowish green, through dark green, maroon, brown, and reddish brown, to purplish-black. The skin is thin and membranous in *P. drymifolia,* while in *P. americana* it is thick, tough, and even woody or shell-like in some varieties, with an extreme thickness of a quarter of an inch. The fleshy, edible part, lying between the skin and the seed, is of a buttery consistency, creamy to bright yellow in color, often greenish near the skin. It contains a high percentage of oil. Streaks of fine fibers traverse the flesh from the stem to the base of the seed; these make up the vascular system, and are invisible in the ripe fruits of many varieties. Each fruit normally contains a single large seed. The seeds of different varieties vary greatly in shape, being round, oblate, spherical, conical, or of slender form. The seed is inverted in the fruit so that the base is on the side away from the stem and is covered by two seed coats of varying thickness, often adhering closely to one another. The cotyledons are normally two, sometimes three in *P. drymifolia,* white or greenish white in color, and smooth or roughened on the surface. The seed is tight in the cavity in some varieties and loose in others.

AVOCADO DISTRICTS IN CALIFORNIA

The commercial avocado plantings in this state are located almost entirely in climatically favored areas in southern California. The most important producing sections occur in the coastal belt extending from San Diego to Santa Barbara, including parts of San Diego, Los Angeles, Ventura, and Santa Barbara counties, and all of Orange County. This region is characterized by very mild winters and cool pleasant summers, with only moderate daily and seasonal fluctuations, the result of the tempering effect of the coastal influence. The relative humidity is normally moderately high. A second climatic zone in which commercial avocado plantings occur consists of naturally protected areas on the foothill slopes of the Santa Paula, San Fernando, San Gabriel, and Santa Ana valleys, including Fillmore, Chatsworth, Pasadena, Monrovia, Duarte, Redlands, Riverside, and North Whittier Heights. This region is cut off from direct coastal influence and as a result is characterized by greater seasonal and daily fluctuation in temperature and humidity. The winters are somewhat colder and the summers considerably warmer and drier than in the coastal belt. In between these two general regions are the intermediate districts such as Hollywood, Whittier, La Habra, Vista, Escondido, and La Mesa. In general it may be said that the avocado plantings are for the most part confined to the milder sections of the citrus belt. Plantings in

the Coachella and Imperial valleys have proved unsuccessful, probably because of the extreme atmospheric dryness and the intense heat.

The avocado has been planted in central and northern California in many scattered localities. Trees are fruiting in Fresno, Tulare, Butte, and other counties, and in sheltered locations in the San Francisco Bay region. They are for the most part Mexican seedlings but indicate that commercial varieties may be developed for these sections. Commercial plantings in these districts are still to be regarded as experimental.

California is justifiably noted for remarkable variation and diversity of climatic and soil conditions within relatively small areas. The success of a crop on a given site is therefore by no means a safe criterion on which to predict the success of the same crop on areas close by. This fact is especially important in its application to the selection of land for avocado plantings, on account of the extreme sensitiveness of this fruit to unfavorable environmental conditions. Thus, in the commercial areas above mentioned, by no means all of the land is adapted to avocado culture. In selecting a site for an avocado orchard it is, therefore, highly important that accurate information be obtained as to climatic, water, and soil conditions. It is certain that many of the avocado plantings made in recent years will prove unsuccessful on account of unfavorable environmental conditions. Information concerning climatic conditions, and particularly the frost hazard, may be obtained from representatives of the United States Weather Bureau. Data bearing on soil conditions are available in the various soil survey reports. *Prospective avocado planters are advised to consult the County Farm Advisor before selecting the site for the orchard.*

CLIMATIC REQUIREMENTS

The avocado is a subtropical fruit and its commercial culture is therefore limited to localities of relatively mild winters such as occur only in tropical and subtropical regions. While in general avocado and citrus trees exhibit somewhat the same range of climatic adaptation in California, it is already clearly evident that on the basis of the varieties grown at present the commercial culture of the avocado is destined to be fully as restricted as the lemon, if not more so. Varieties of the Mexican race appear to have about the same range of climatic adaptation as the navel orange but the commercial future for varieties of this race is problematical to say the least. Varieties of the West Indian race are so tender to low winter temperatures

that they have succeeded only in very limited areas where very mild winters occur. Varieties of the Guatemalan race exhibit a considerable range of climatic adaptation, but in general may be said to succeed only where the production of spring and summer-bearing lemons is successful. In recent years an interesting climatic relation has been fairly well established, namely that the Guatemalan varieties appear to succeed best under conditions where the winters are rather too mild for the Santa Barbara soft-shell walnuts.

The principal climatic factors limiting the culture of the avocado in California, in the order of their importance, appear to be low winter temperatures, high spring and summer temperatures, and low atmospheric humidity during the blooming and setting period in the spring. The relative importance of low winter temperatures is concerned primarily with their frequency of occurrence, the degree of temperature reached, and the duration of injurious temperatures. Where damaging winter temperatures are relatively infrequent and local topographical and meteorological conditions favorable, this factor can be successfully and profitably combatted by means of orchard heating. The summary here quoted, made by Webber[3] after the winter of 1916–17, gives in general reactions of the tree to the different degrees of low temperature experienced:

30° F—Nothing injured so far as could be observed.

29° F—No injury of account; only traces on most tender growth of West Indian and Guatemalan varieties.

28° F—New foliage scorched on Guatemalan type; West Indian varieties showing considerable foliage damage.

27° F—Mexican varieties showed new tips slightly scorched; Guatemalans showed almost all new foliage injured; West Indians badly damaged.

25° to 26° F—Mexican varieties showed new foliage injured but some dormant trees uninjured; all Guatemalan sorts showed new foliage badly injured and some old foliage scorched.

24° F—Some dormant Mexican varieties injured; Guatemalan varieties badly injured, small limbs frozen back.

21° F—All Guatemalan types killed to bud; a few of the hardiest Mexican varieties, such as Knowles and San Sebastian, with young leaves only injured.

Exceptions occur because of peculiar local conditions and variations in the vigor of individual trees. Varietal differences occur within the two races and will be mentioned later (fig. 3).

[3] Webber, H. J. Cold resistance of the avocado. California Avocado Association Annual Report 1917:49. 1918.

The avocado is also sensitive to hot summer temperatures. This factor is the main reason for its failure in the hot, dry, interior sections. Intense heat waves in the more favorable districts have caused serious damage in the past. Two varieties, the Caliente and the Tiger, have shown some promise of heat resistance in the more arid districts.



Fig. 3.—Variation in frost resistance of seedling avocado trees of the Guatemalan and Mexican races. They were located in an exposed section of the San Gabriel Valley of Los Angeles County, with no frost protection. The injury was caused by the freeze of January, 1922. (From Bul. 365.)

Atmospheric humidity is a factor of importance, as is evidenced by the behavior of the avocado in different parts of the state. Production is consistently heavier in the more humid coastal districts than in the hotter and drier interior regions. Dry atmospheric conditions are unquestionably detrimental to the setting of the fruit.

Since avocado culture in California is possible only by means of irrigation, the question of rainfall is not of importance except as it insures an adequate supply of irrigation water.

Wind has an important influence in avocado culture and is discussed in another section.

On account of the wide variation in climatic conditions within relatively small areas, the greatest care should be exercised in the selection of a site for the avocado orchard. *Not until all the information available has been obtained should a definite choice be made.* If then it appears that the climatic conditions are suitable, choice of varieties should be made on the basis of both climatic and economic considerations (see sections on varieties).

SOILS

Observations on the behavior of the avocado in California indicate that it thrives on a wide range of soils. Commercial plantings are found on the very light sandy soils, on the heavy black adobes, and on the many different types between these two extremes. It seems to do best, however, on the medium-textured soils. For satisfactory results a depth of at least 3 feet is required. *The avocado is extremely sensitive to poor drainage and will not endure a saturated soil for more than a few days.*

In selecting the site for the avocado orchard the character of the subsoil should be most carefully determined. Structural faults, such as clay layers, limestone, or hardpan close to the surface, are especially unfavorable on account of the intolerance of the avocado for poor drainage. For this reason soils with these subsurface characteristics should be avoided.

California soils are notably variable in texture, structure, depth, and other characteristics. While the soil-survey reports are remarkably accurate and consequently exceedingly helpful, obviously they cannot picture in detail the local soil variability. This can only be determined by personal examination with a soil auger or tube. Time spent in studying the soil conditions is unquestionably in most cases a profitable investment for the prospective avocado planter. He will also usually find it advisable to consult the Farm Advisor in the county in which the land is situated.

PROPAGATION

Rootstocks.—Experience in handling and growing budded avocado trees during recent years has indicated the need for more information concerning the choice and selection of rootstocks. In the early years of the industry any kind of seed procurable was used to raise seedlings—West Indian, Guatemalan, or Mexican; large, small, mature, and immature—with the result that many nursery trees failed to make a satisfactory growth, and many young orchard trees failed after

planting. The West Indian seedlings were early discarded because of their tenderness to frost; and because of the more plentiful supply of seed of the Mexican varieties for some years most of the trees were propagated on this stock. In recent years, however, the situation has changed materially, in that seed of the Guatemalan varieties has been available in much larger quantities than that of the Mexican varieties. This, coupled with the fact that avocado seed cannot be brought in from Mexico on account of the avocado seed weevil, has resulted in the propagation of many trees on the Guatemalan stock. These trees are unquestionably vigorous and thrifty; the greater susceptibility of this stock to frost, however, is a factor which should be given serious consideration in connection with its use. While the Mexican stock is generally preferred for this reason, it should be pointed out that the evidence bearing on compatibility between stock and scion, though small in amount, clearly favors the Guatemalan stock. There is need for investigation on this subject.

The wide variation in Mexican seedlings, which has become especially evident in recent years, leads to the conclusion that many of the seeds represent natural hybrids resulting from cross pollination from nearby Guatemalan trees. It is possible, however, on the basis of the leaf and coloration characters exhibited by the seedlings, to eliminate many, if not most, of the hybrid seedlings; and a number of the nurserymen now follow this practice regularly. Seedling variation from this cause would undoubtedly be greatly minimized if seed were taken only from isolated trees or solid plantings of Mexican varieties where the opportunities for natural hybridization are remote. There are, however, notable differences in the behavior of the seedling progeny of isolated trees of the Mexican race. Some exhibit much more variability in size and vigor in the seedling progeny than do others, and hence are much less desirable sources of seed. At least one excellent Mexican seed parent tree has been discovered. There is need, however, for many others and investigations along this line should be initiated as soon as practicable. On account of its remarkable vigor, large numbers of trees have been propagated in recent years on seedlings of the Fuerte variety, which seem to be fairly uniform and vigorous.

Seed is generally obtained from dealers, of whom there are several specializing in avocado seeds, or from the cooperative marketing agency. The seed should be from fully matured, well-developed and well-shaped fruit, rather than from undersized and immature fruit. Standardization of avocado seed used for nursery purposes is an important need in the industry.

Growing the Seedlings.—Avocado seeds are usually sprouted before planting in the nursery, although the practice of planting the seed direct in the nursery rows has come into favor in recent years. The latter practice necessitates irrigation by sprinkling, for this is the only means by which favorable moisture conditions can be maintained while the seeds are sprouting. There are advantages and disadvantages to both methods. Where the seeds are sprouted before planting the opportunity exists, if the planting is done carefully, to have the greater part of the spaces in the nursery rows occupied by usable seedlings. On the other hand there is but little question that the transplanting gives the seedlings a decided setback. Where the seeds are planted direct, unless they are selected very carefully and given the best of care there is certain to be a considerable percentage of spaces where the seeds either fail to grow or grow slowly. The good seedlings, however, make an early start and vigorous growth and reach the budding stage early. In both methods there are bound to be some seedlings which should be discarded either because of weak growth or evidence of undesirable parentage.

The old method, now fortunately almost entirely discarded, was to sprout the seeds in boxes or beds, or in 4-inch pots, transplant them to larger pots, repotting from time to time, and either to bud the trees and grow them in large pots, boxes, or cans, or to transplant them to the nursery row before or after budding. These practices, with the majority of the trees, produced curled roots, the result of their becoming pot-bound. Most of these trees failed to grow satisfactorily after planting in the orchard and subsequenty either died or had to be removed.

Sprouting is now accomplished almost entirely in beds containing a mixture of sand and soil. A mixture of equal parts of clean sand and loam is commonly used. The buds are usually 6 to 8 inches deep and are sometimes made over a hotbed, though usually not. The seeds are planted with the base or largest end downward and the pointed end or apex barely protruding above the soil. The soil should be kept moist by frequent sprinkling but should not be kept soaked. During hot weather muslin or lath screens are placed over the beds during the hottest part of the day. It is best to plant the seeds as soon as possible after removal from the fruit, but they may be kept several months if not permitted to dry out. Since the Mexican varieties normally ripen in the fall or winter most of the seeds are planted at that time of the year. If weather conditions are favorable, germination starts within a few weeks and proceeds slowly until early

spring when the advent of warmer weather hastens it. The seedlings are usually ready to be transplanted in March or April, by which time they have attained a height of 4 to 8 inches.

A few nurserymen follow the practice of sprouting the seeds in large bottomless paper pots, in which they are transplanted to the nursery. This practice undoubtedly minimizes the setback incident to transplanting but is somewhat more expensive than the sprouting method above described.

When danger of frost is over and the seedlings have reached the height mentioned, they are usually transplanted directly to the nursery rows and set out, 14 to 18 inches apart in the row, the rows being 30 to 36 inches apart. It is considered good practice to clip off about two-thirds of each expanded leaf at the time of transplanting. Irrigation should immediately follow planting to prevent drying out. If the weather is unusually warm, temporary protection from the sun is necessary and is usually provided by placing a shingle on the south side of each seedling. Frequent watering is necessary until they become established; after that irrigation every two weeks should be sufficient excepting in extremely hot weather.

Budding.—Although the budding operation itself is simple, the results obtained, even by skillful budders, are often far from satisfactory. The reasons for this situation are by no means fully understood. It has been the experience that certain varieties, including the Sharpless, Dutton, Carlsbad, and others, are much more difficult to propagate by budding than most of the other varieties. This may indicate a narrower range of scion-stock compatibility on the part of these varieties, or it may be due to a less favorable physiological condition in the budwood as ordinarily handled. In this connection it is of interest to observe that a number of budders claim that they get much better results with all varieties if several weeks prior to the cutting of budwood the leaves subtending the buds to be used are removed or cut back, or the leaf-stalks broken. The proper selection of budwood unquestionably has much to do with both the success of the budding operation and the subsequent growth of the buds. How properly to select budwood is largely a matter of experience, for varieties differ greatly in this respect (fig. 4). Some produce fairly large numbers of good buds; others, comparatively few. In general, recent growth that is well matured, with fairly plump buds, and that does not snap on bending, furnishes the best type of budwood. But not all of the buds on a given shoot are equally suitable for use. While the lower, and usually underdeveloped buds will ordinarily 'set' or



Fig. 4.—Desirable budwood of four commercial varieties: (1) Taft; (2) Anaheim; (3) Nabal; (4) Fuerte.

'stick,' they usually fail to grow. On the other hand the upper buds, which are usually well developed, after 'setting' frequently abscise or shed the 'eye' or growing point and consequently fail to develop. It is usually best, therefore, to use only buds taken from the mid-section between the growth nodes.

It is often necessary or desirable to store budwood, which may be done successfully for a month or six weeks, by packing it in moist sphagnum moss, sawdust, or sand which should be kept moist but not wet. Budwood should be stored in a cool place. The use of stored or 'cured' budwood has several advantages. During storage, abscission of the 'eyes' of overdeveloped buds usually occurs. This prevents the use of these buds, which otherwise might be inserted only to have the growing points shed later. Stored budwood is also less tender and can be successfully handled with less care than fresh budwood.

Seedlings to be used for budding should be kept in a thrifty, growing condition. They may be budded anytime during the season when the sap is flowing freely, after they have attained a diameter of half an inch. Usually this occurs early in the spring, March and April being the usual months for the operation. For budding during these months, well-matured wood from the previous season's growth may be used. After active growth has commenced, suitable buds are not available until the new growth has hardened, usually by the latter part of July. At this time budding can again be commenced and continued until late in the fall. A certain percentage of the buds inserted in the fall will push out and make some growth and will require extra protection during the winter. Only buds put in very late in the fall can be counted on to remain dormant until spring.

Shield budding, such as is used in the propagation of citrus and deciduous fruits, is the common nursery practice. A 'T' or inverted 'T'-shaped incision is made within 2 or 3 inches of the ground, preferably on the north side of the seedling. The bud is cut with a shield not less than 1¼ inches in length, and is pushed gently into the incision. The stock should be in such condition of growth that the bark will slip readily, and will not require lifting by the knife blade, otherwise it is too dry to be used successfully.

The knife blade used for cutting buds should be thin and should be kept at a razor edge. The cut should be made parallel to the surface of the stick with a single, sliding motion; much of the success of budding depends on having the cut uniform, smooth, and straight.

After insertion, the bud is immediately wrapped, the usual practice being to leave the eye uncovered. Various materials are used: raffia, cotton twine, rubber bands, muslin, and budding cloth. Budding cloth

is recommended, provided a hard wax is used in its manufacture which will not melt and injure the bud in hot weather. A wax composed of 1 pound of beeswax and ¼ pound of rosin is satisfactory. Cheap grades of muslin are made up into rolls 6 inches wide and 1 inch thick, and boiled in the wax for 15 minutes.

About three weeks are required for the buds to unite with the stock, during which period they should be examined and the wrapping loosened to prevent binding. The top should be pinched back at this time in order to start the bud into growth. From six to eight weeks after budding the wraps may be safely removed. It is a mistake, however, to remove the wrapping from the point of insertion until the bark flaps are healed and there is no further danger of their spreading open. After another month of growth the seedling should be cut back still further, leaving some foliage to take care of the sap flow. When the bud has made a growth of 4 to 6 inches it should be tied up to the stock with raffia; staking should be done when it has reached a height of 16 to 18 inches. The seedling top should not be cut off until the bud has grown at least 2 feet; this operation is best done when the top has become somewhat hardened. A sloping, smooth cut close to the bud union should be made and the wound painted over with grafting wax.

Since avocado trees are best planted during the spring months the object of the nurseryman is to have as many of his trees as possible ready for sale and delivery at that season of the year rather than during the fall months. The nursery trees grow so vigorously that it is difficult and usually impracticable to attempt to hold unsold or unused trees over another planting season. If conditions are favorable and good care is given, seeds sprouted in the fall or winter should be ready to bud the following summer or fall and ready to plant in the orchard a year from the ensuing spring, a total of 28 to 30 months from the time the seed is planted.

Balling.—It is the customary practice to ball the trees prior to the starting of growth in the spring, and to hold them in the lath-house until planting time (fig. 5), although some nurserymen prefer to delay balling the trees until ten days or two weeks before they are to be planted in the orchard. A few days before balling, the trees are cut back or partially defoliated, or both, to balance the loss of part of the root system. The cuts should be waxed to prevent excessive evaporation. A ball of earth 10 to 12 inches in diameter and 14 to 18 inches in length is removed with each tree. The trees are then hardened off by storing under lath until planting time. Care must be taken to keep the balls moist but not wet.

Some experiments have been tried of planting budded avocados with bare roots, but these have not been very successful, and the practice cannot be recommended.

Nursery-Tree Standards.—Until recently avocado trees were sold by height, a premium being paid for the tall trees. It became apparent some years ago, however, that the tall, slender trees frequently did not do so well in the orchard as the shorter and more bushy trees. They often failed to make much growth for several years, while the smaller trees generally started off immediately and within a year or two were ahead of the originally larger trees.



Fig. 5.—Well-grown avocado nursery stock stored in lath-house awaiting shipment. Photo by J. E. Coit.

This experience has brought about a rather marked change in nursery practice in recent years, and the majority of the trees are now graded by caliper, the measurement being taken an inch above the bud union. It has been found that if the trees are not forced to grow tall, but are permitted to assume a bush habit, they are stockier and do better when set out in the orchard. Such trees do not require expensive staking and protection from sunburn, though wind protection is necessary, regardless of the type of nursery tree.

At least one of the larger avocado nurseries now sells all trees on the basis of two grades, guaranteeing the buds to be from bearing trees of good yield record, and the stocks to be of pure Mexican

parentage (fig. 6). The relatively high cost of nursery trees and of bringing an avocado orchard into bearing makes it especially important that only the best possible trees be used. Buds from record trees in fruit usually sell at from 3 to 5 cents each.

Topworking.—The occurrence of many unproductive or inferior types of seedling trees and the need for converting trees of undesirable or unprofitable varieties to better sorts has created much interest in methods of topworking. A number of successful methods have been developed; of these, budding and fit cleft grafting are the most widely used.

The oldest method, still commonly employed, is to cut off the branches a foot or two from the main crotch and to bud three or four of the new shoots which develop near the cut ends of the stubs. It is usually best to distribute the conversion process over two or three seasons, topworking only part of the tree at a time. This method is slow but also simple, for which reason it is preferred by some growers. It is no longer regarded as the best method.

Another method, not so much used now as formerly, is to insert the buds directly into the bark on the trunk or main branches close to the main crotch. This method has the advantage, where successfully employed, of saving approximately a season in the time of conversion to a new top. From one-third to one-half of the top is first removed by a thinning-out pruning. The trunk and the limbs exposed should be given a coat of whitewash to prevent sunburn. From two to four buds are inserted in each of the branches to be budded in such a manner that one wrapping suffices for all. One or two unbudded 'safety' limbs are generally left to nourish the roots and equalize the sap flow until the new head is established, after which they are removed. Buds are taken from mature wood ½ to 1 inch in diameter. They are cut to a length of about 2 inches, the upper or lower end being cut off square, according to whether the ordinary 'T' or inverted 'T' incision is used, to facilitate forcing the bud into the incision. Where the bark is very thick it is scraped as an aid to easy insertion. The wrappings commonly used are No. 16 heavy cotton cord or strong budding cloth; the buds are wrapped tightly, leaving only the eye exposed. The wrappings should be left on for at least two months, since if removed earlier the bark flaps have a tendency to lift away from the bud. Sucker growths are removed to assist in starting the buds into growth, and notching or girdling above the buds is frequently of assistance in this connection. The new buds are carefully tied to the limbs to prevent breaking.



Fig. 6.—Grade *A* avocado nursery trees. Left, Fuerte; right, Nabal.

The budded limb should not be cut back until the new growth has become somewhat hardened and is able to take care of the sap flow; this operation is usually done the following season. It may be necessary to pinch back the bud shoots to encourage early branching. Budding can be done only when the sap is flowing freely and the bark can be raised easily, usually from April to November. For budding into old bark cured budwood is often advisable.

During recent years topworking by grafting rather than by budding has rapidly increased in favor, largely because of the time saved in effecting the conversion process. The only important drawback to the use of this method is the relatively high cost of scions.



Fig. 7.—Bark-grafted avocado limb. The cut surface and the cut ends of the scions should be protected by a waterproof coating. (From Bul. 365.)

Few can be taken from any one tree because of the excessive amount of cutting back required to secure them. Where trees have well-formed heads consisting of two or three well-shaped framework limbs, a new head can be established by inserting two scions in each, eventually removing one of the scions if both take, leaving the more vigorous. The limbs not used for grafting are gradually removed as the new top develops and is able to use the entire sap flow. Very large trees with no branches close to the ground can be successfully reworked by cutting off the trunk at a height of about 4 feet and inserting at least four scions. Special precautions must be taken to keep large

wounds well protected against the entrance of heart-rot fungi, by the use of waterproof paint or wax. Avocado wood is unusually brittle, and in sawing off limbs to be grafted the first cut should be made about a foot or more above the point where the scions are to be inserted. This is done to prevent splitting, and permits the second cut to be made clean and smooth. The scions should be of second-growth wood, well matured, and should have two or three buds well placed, plump, and well formed, but not far advanced. It is especially desirable for the scion to include a node so that advantage may be taken of the many adventitious buds arising in that zone. This insures growth, once union is effected.



Fig. 8.—Side-grafting of the avocado. This method can be used any time when the bark slips readily. (From Bul. 365.)

Two general types of grafting have been used successfully, bark grafting and cleft grafting. Both standard bark grafting, in which the limbs are cut off before grafting (fig. 7), and side grafting (fig. 8), where they are inserted and allowed to grow for some time before the branches are cut off, have been successfully employed. The scions are cut with a long sloping cut on one side only and are pushed down between the bark and the wood or in side grafting into a 'T' shaped incision. It is sometimes an advantage to nail them tightly in place,

care being taken not to split or bruise the scions during the nailing process. They are then tied or wrapped securely and all the cut surfaces waxed or sealed. Bark grafting, like budding, can be done only during the active growing season, for success depends on the easy lifting of the bark.

The standard method of cleft grafting was formerly used to a considerable extent but is now rapidly passing into disfavor. In this method the branches to be grafted are cut off and the scions inserted in clefts made either by splitting or sawing (fig. 9). The scions are



Fig. 9.—Avocado tree topworked by cleft grafting. Note the nurse limbs left, whitewashed trunk and branches, and paper bag protectors. (From Bul. 365.)

cut wedge-shaped, tapering for a distance of 1½ to 2 inches, depending somewhat upon the size of the wood used and the limbs to be grafted. The cuts are also tapered slightly from front to back, giving a slight wedge shape, enabling the scion to fit more closely into the cleft. Much of the success in topworking depends upon making the cuts smooth and even, and the knife used for this purpose should be

kept at a razor sharpness by means of frequent stropping. The cleft is made with a heavy knife, care being taken to split the limb some distance beyond that required by the length of the scions. This reduces the pressure exerted on them. The edge of the cleft should be trimmed smooth with a sharp knife. A hardwood wedge is driven



Fig. 10.—Nineteen-month-old top developed from one scion inserted by the Renshaw method. This method has the advantage of materially shortening the conversion period.

into the center of the cleft and the scions fitted so that the cambium layer of the scion and that of the stock coincide as closely as possible throughout their entire length. The wedge is then removed and budding cloth strips half an inch in width are wrapped tightly around the end

of the limb. Grafting wax is painted over the surface of the cuts and poured down into the cleft so as to fill it and the tops of the scions are tipped with wax. If the bark is thick, necessitating the setting in of the scions, the space between the bark and the scions is also filled with wax before the budding cloth is applied. The operation is completed by placing a paper bag over the end of the limb, cutting small holes for ventilation. This is not removed until the scions have made a good start. The trunk and branches should be protected against sunburn, preferably by whitewashing.

There has recently been developed a modified cleft graft, known popularly as the Renshaw method, which is rapidly displacing other methods of topworking and appears to possess a number of advantages (fig. 10). This method is in reality a fit cleft graft (fig. 11), and also involves much more drastic cutting back than has ordinarily been practiced in grafting. Trees grafted by this method are often cut back to the main trunk. Instead of splitting the stubs after cutting off the branches, they are deeply notched with a saw. Large scion wood is used, the scions usually being cut rather short, with one or two buds. These are cut so as to exactly fit the notches and are driven tightly in place. Then all cut surfaces are waxed and the sacks attached, and the trunk and branches whitewashed.

Cleft grafting was formerly thought to be successful only when the sap flow was slow and the bark not easily raised. Experience during the past season or two, however, has shown this to be an error, and apparently it can be used successfully at practically any time of year excepting the fall months.

Whatever the method of topworking may be, the follow-up work is of special importance. It is necessary to go over the trees frequently and remove the suckers, confining the growth to the buds or scions. They will also require pinching or pruning to cause them to branch and produce a mechanically strong branching system. In the case of grafting, re-waxing of the stubs may be required to prevent the drying out and failure of the scions. Supports are usually necessary for the rapidly growing bud shoots or scions or they are likely to break out. All large cut surfaces will need occasional treatment to prevent the entrance of organisms causing wood decay. Cleft-grafting methods have the advantage that in the event of failure of the scions, the new shoots arising from the cut ends of the branches can be thinned and budded in the same manner as nursery seedlings. They are usually large enough for budding by June or July.

Various kinds of grafting waxes and wound compounds are used, the most common being compounds of beeswax and rosin or paraffin. In recent years a commercial preparation, bitutect, which appears to be a water-asphaltum emulsion, has come into prominence and is now rapidly displacing all others.



Fig. 11.—Two seven-month-old scions inserted by the Renshaw method.

Seedlings and named varieties exhibit a wide variation in the ease with which they may be worked over to some other desired variety. The Taft seems particularly difficult to topwork by cleft grafting; some others behave in a similar manner. The congeniality between the variety to be topworked and the desired variety should be learned if possible before attempting the operation.

ORCHARD MANAGEMENT

Laying Out the Orchard.—Two general systems of planting are in use: the square system, adapted to the gently sloping and more level lands, and the system of terrace planting employed on the steeper hill slopes. In the ordinary square system planting distances vary from 20 by 20 feet to 40 by 40 feet, according to the variety. Some of the tall, upright-growing varieties have been planted even closer. The Fuerte and other spreading varieties are usually planted from 25 to



Fig. 12.—Sixteen-year-old avocado orchard, with trees planted 24 feet apart. They are now interlacing and will soon be crowding.

40 feet apart. It is now clearly apparent that most of the commerical plantings have been set too close (fig. 12) and that unless severely pruned, which seems inadvisable, the avocado as an orchard tree must be expected to materially exceed citrus trees in size. It would appear advisable, therefore, for avocado planters to profit by the experience of the walnut growers and adopt a double planting system which would permit the removal of part of the trees when crowding occurs and leave the permanent trees at a satisfactory distance, 30 by 40 feet or more. Varieties selected for interplanting should have either an upright slender habit of growth or early bearing qualities.

In recent years the development of hillside lands for avocado plantings has come into considerable prominence. On account of the protection from frost afforded by the elevation, extensive hillside plantings have been made, especially in the North Whittier Heights, La Habra, and Vista districts (fig. 13). This system of culture is of course more expensive because of the greatly increased cost of laying out the orchard and the higher costs of orchard-management practices. The limit of steepness of slope beyond which it is not practicable to terrace is estimated to be about 25 degrees. The grade contour varies from 1 to 2½ per cent, according to the distance the irrigation water will have to flow. The width of the terraces varies from 7 to 16 feet, the latter distance being considered the better when the slope permits.



Fig. 13.—Construction of terraces for an avocado orchard near La Habra, Los Angeles County. Photo by H. J. Webber. (From Bul. 365.)

With narrow terraces nearly all cultivation must be done by hand. The trees are planted from 2 to 5 feet inside the edge of the terrace to permit running irrigation furrows on both sides. The cost of terracing hillside land varies from $100 to $150 per acre, according to the steepness of the slope and the character of the soil. When possible, grading should be done so that winter rains can have the opportunity of settling the terraces and indicating any irregularities that may interfere with the flow of irrigation water. It is advisable to run water down each terrace as a final test before planting the trees; changes in the grades are difficult to make after planting has been done. The terraces are spaced so that the tree rows are approximately 30 feet apart; this varies according to the slope and contour

of the hillside. They may be brought closer together or spread wider apart, necessitating the elimination of some of the planting, or the addition of short rows in between to insure filling the entire space. Special care is necessary during the rainy season to prevent excessive erosion. Adequate surface drainage must be provided; this is usually done by sloping the terrace inward. The control of weeds is more difficult on terraced plantings, because of the banks between terraces, which cannot be cultivated by horse or tractor-drawn implements. The trees are planted 15 to 40 feet apart on the terraces, according to variety.

The practice of interplanting citrus and avocado trees or replacing diseased or decadent citrus trees by avocados is on the increase and bids fair to become an important method of establishing avocado orchards, especially in the old citrus districts. By this means some income from the citrus orchard is received while the avocado trees are coming into bearing, and the citrus trees offer considerable protection to the young avocado trees.

Planting and Care of Young Trees.—It has been the experience in California that young avocado trees are much more tender than citrus trees, and hence require more care and attention, at least during the first few years. The usual methods of planting and caring for citrus trees have frequently resulted in serious losses in young avocado orchards. On the other hand, if properly planted and attended to, avocado trees grow rapidly and within a few years outdistance citrus trees of the same age.

It is almost the universal practice to ball avocado trees in the nursery, even though they may be grown for planting only a short distance away. This practice is unquestionably to be recommended, as the young nursery-grown trees are exceedingly tender and very easily injured by exposure or careless handling. Especial care must be exercised in handling the trees after they have been balled. They should never be picked up by the trunk or dropped to the ground even though the distance be short. The tearing away of the tender, fibrous roots and the breaking of the contact between roots and soil incident to such treatment are almost certain to delay the starting of growth until several months after planting, during which period sunburn is likely to occur.

In deep, fertile soils the digging of large holes is unnecessary, but in many soils experience has shown the advisability of digging large holes and filling in with top soil. On account of the extreme sensitiveness of the bark to sunburn, the bud-unions should be faced away from the afternoon sun. The soil should be thoroughly firmed about the

ball before irrigation, rather than settling the soil by running water in the partially filled holes. Placing manure or other fertilizers in the holes is not recommended as it is likely to result in injury to the young, tender roots. Pulling back the corners of the burlap coverings of the balls and covering them with soil at the time of planting is advisable, because this permits better contact between the soil in the ball and that in which the trees are planted. The young trees should never lack for moisture; they should be irrigated immediately after planting and at frequent intervals thereafter until well established. The interval may then be lengthened to two or three weeks in accordance with soil and climatic conditions.

Protection against sunburn was of especial importance for the slender, upright nursery trees formerly used, as was also staking to prevent wind damage. With the more compact trees of the type now most commonly used these precautions are not necessary, though some type of wind shelter or screen is advisable in all regions of either occasional or prevailing winds.

Cultivation to prevent the growth of weeds around the young trees is essential. The surface soil should be maintained in proper physical condition to take water readily. Some growers have found it a good practice to make basins and mulch the surface around young trees with bean straw or alfalfa straw. This practice appears to be especially effective where the soil in the balls is heavier in texture than the soil in which the young tree is set.

Care of Mature Orchards.—Cultural operations in mature avocado orchards differ little if any from those in citrus orchards. Spring plowing or disking and summer cultivating are usually practiced. The cultural operations should be designed primarily to maintain conditions favorable to the penetration of irrigation water. Weeds should be kept down. On terraced plantings, plowing one way in the spring is about all that can be done, and on narrow terraces is accomplished with difficulty, if at all. As the trees spread out and cover such terraces the point is reached when hand work alone must be relied on.

Since the avocado is by nature a shallow-rooted tree, deep cultivation or abrupt changes in depth of plowing or cultivating are likely to cause injury, which is often exhibited in an excessive shedding of the young fruits.

Irrigation.—In general the water requirement of avocado trees is similar to that of citrus trees of the same size. Both are native to regions of high rainfall that comes mainly during the growing season. The root system of the avocado is similar to that of the citrus trees, the feeding rootlets being fibrous and located for the most part in the

upper 3 feet of soil. Hence irrigation practice with these fruits is similar in all important respects. Both require the presence of available moisture in the soil at all seasons of the year, and yet, under many conditions at least, citrus and avocado trees have been severely injured by excessive irrigation even where soil drainage is good. This seems to have been brought about by attempts on the part of many growers to maintain the soil moisture at a relatively uniform point.

There is much reason for believing that citrus and avocado roots are most active when the soil moisture is at a point considerably lower than the normal field capacity of the soils in which they are located. If this be true then the soil moisture should fluctuate from its normal moisture-holding capacity to some point approaching the wilting coefficient. That permitting the soil to dry out appreciably between irrigations is definitely beneficial to the growth and fruitfulness of both avocado and citrus trees has been amply demonstrated in recent years; and that this practice, unless carried so far as to cause pronounced wilting, cannot result in injury from lack of moisture has been adequately established from experiments conducted in the California Agricultural Experiment Station[4] and elsewhere. These experiments have shown that the use of water by plants is independent of the amount in the soil as long as the moisture content is above the wilting point.

The amounts of water required by avocado trees vary greatly in different parts of the state, and depend mainly on the age and size of the trees and climatic conditions. In the hot interior regions good bearing trees require the equivalent of 35 to 40 inches of rainfall, while in the coastal areas 25 to 30 inches appears to be sufficient. Since the rainfall in the avocado districts is in general less than the total requirement of the trees, and in addition comes altogether during the winter months, irrigation is required to make up the deficiency and to supply the needs of the trees during the dry growing season. This is usually accomplished by applying 3 to 4 acre-inches[5] of water at each irrigation. The interval between applications should be determined by examination of the soil. The only satisfactory way to determine moisture conditions is to examine the soil to a depth of at least 4 feet. This can best be done in most soils with a soil auger, or posthole auger. This should be a regular orchard practice.

[4] Veihmeyer, F. J. Some factors affecting the irrigation requirements of deciduous orchards. Hilgardia 2(6):125–291. 1927.

See also: Beckett, S. H., Harry F. Blaney, and Colin Taylor. Irrigation water requirement studies of citrus and avocado trees in San Diego County, California, 1926 and 1927. California Agr. Exp. Sta. Bul. 489:1–51. 1930.

[5] An acre-inch is approximately equivalent to the flow of 1 miner's inch of water in 50 hours or, conversely, 50 miner's inches flowing for 1 hour, on 1 acre.

Methods of applying irrigation water to avocado orchards vary. The prevalent practice is the use of furrows; this method gives satisfaction where the slope is not too steep and the soil not so porous as to result in loss of moisture and plant food by excessive penetration. For terrace plantings (figs. 14 and 15), furrows should not exceed 300 feet in length; for ordinary conditions furrows from 300 to 400 feet in length, depending on the character of the soil, are most satisfactory. The use of cross furrows to supply water in the dry portions of the tree rows is recommended.



Fig. 14.—The furrow system of irrigation commonly used on terraces. The length of the furrows should not exceed 300 feet. (From Bul. 365.)

The mulched-basin system (fig. 16) has been tried with varying success. Poorly drained basins in heavy soils have been known to cause the death of trees from suffocation. Opinions differ in regard to the ultimate success of the mulched-basin system. Some growers have discontinued its use, while others continue to use it in new plantings. It reduces the amount of cultivation, is conducive to the maintenance of favorable soil moisture and temperature conditions, and supplies organic matter to the soil, if sufficient mulching material is kept in the basins. On the other hand, the basins are costly to install, especially on steep slopes, and are expensive to maintain. Their use

on heavy soils is also likely to result in overirrigation and consequent injury to the trees.

On the lighter soils flooding is necessary to get the water evenly distributed over the entire area, since a sufficient head cannot be maintained to carry the water down furrows.



Fig. 15.—Special equipment has been developed for irrigating hillside plantings. The distributor shown above is used where the pipe line passes down a ridge with the furrows sloping each way from it. The distributor is jointed so that it can be raised vertically to be out of the way of cultural operations. (From Bul. 365.)

In recent years much attention has been given to overhead irrigation in avocado orchards (fig. 17), owing to its extensive adoption by citrus growers. This method appears to have several advantages. Furrowing out is not required, and once the water is turned on but little attention is needed. A modified sprinkler system has been tried

under the trees, but is not so successful because the limbs usually have to be cut high to allow the spray to spread. This leaves the trunks less protected during cold weather and serious damage from freezing has resulted. The cost of installing the overhead system varies from $100 to $350 an acre, according to the type of equipment used.

The drip system has been used by some growers, but does not give an even distribution of moisture, often results in overirrigation, and cannot be depended upon to meet the requirements of the trees during the growing season.



Fig. 16.—Young bearing avocado trees under the basin-mulch system of culture.

As already mentioned, the question of drainage is of equal importance to that of irrigation. The avocado tree requires an abundance of water, but it must also have thorough drainage—both surface and subsoil. The tree is markedly intolerant to standing water or waterlogged soils.

Fertilization.—Little is known concerning the fertilization requirements of avocado orchards. Experience in both Florida and California has demonstrated a marked response to applications of nitrogenous fertilizers, but so far as can be determined no carefully planned fertilizer experiments have ever been conducted on the avocado. The

results of citrus fertilization studies afford the best information available at the present time, and they are believed to be applicable to the avocado, at least to a considerable degree. Studies of the soils in the citrus districts of southern California have disclosed that they are for the most part relatively well supplied with potassium and phosphorus, two of the three elements commonly applied in fertilizers. These two require only the presence of decaying organic matter to make them available. California soils are, however, prevailingly deficient in nitrogen and organic matter, and these materials are applied to mature citrus orchards in large quantities as a demonstrated means of maintaining satisfactory production.

The amounts of plant-food elements removed from the soil by avocado trees are undoubtedly as large as those removed by citrus trees. The avocado fruit is high in mineral content and in protein, and it is not improbable that avocados remove larger amounts of plant nutrients from the soil than a corresponding crop of citrus fruits. The whole question must be thoroughly investigated, however, before final recommendations can be made. For mature bearing trees the use of 2 pounds of nitrogen per tree per year is regarded as a safe minimum; at least half of it should be provided from organic sources, preferably bulky manures. No better general fertilizer can be recommended than good barnyard manure. Alfalfa hay and beanstraw are likewise very satisfactory materials when they can be obtained at reasonable prices. These bulky materials are best turned under during the fall of the year. With citrus trees the use of quickly available nitrogenous fertilizers, such as nitrate of soda, sulfate of ammonia, or nitrate of lime, has proved of value in helping to set the crop, when applied from four to six weeks in advance of the blossoming period. There is reason to believe that a similar practice is beneficial to the avocado.

The fertilization of young avocado trees offers a different problem from that of older trees. The excessive use of nitrogenous fertilizers seems to cause many to delay coming into bearing. The incorporation of quantities of barnyard manure in the holes in which young trees are to be planted is not to be recommended except to a limited degree in very heavy, tight soils. In these cases the manure should be placed at the bottom and mixed thoroughly with the soil. Young trees will make a better growth if top soil is used to fill in the holes and if the use of fertilizers is withheld until the trees have come into bearing. Exceptions are to be made, of course, in the case of very poor soils.

Cover crops have long been used successfully as a means of partially supplying the organic matter requirements of citrus trees, and

are being used to some extent in avocado orchards. Winter cover crops—usually purple vetch (*Vicia atropurpurea*) or bitter clover (*Melilotus indica*) are generally used because of winter rainfall. Where irrigation water is plentiful and cheap during the summer months, sweet clover (*Melilotus alba*) may be grown with advantage, especially on heavy, tight soils, because of the action of its large, deep-growing roots in opening up the subsoil and supplying organic matter and better moisture penetration to the lower layers.



Fig. 17.—Typical overhead irrigation installation in an avocado orchard. For convenience in cultural operations the stands are placed in the trees.

Pruning.—No systematic study has been made concerning the pruning of the avocado. However, observations which have been made over a period of some years relative to different practices used by growers, together with principles applicable to other evergreen fruit trees, point to some fairly clear generalizations. The avocado requires little or no pruning once its framework has been established. Some thinning from time to time will be advisable to permit sunlight to reach the inside foliage. In some strong-growing varieties cross branches develop which, if allowed to remain, result in poorly formed tops and severe breakage. Stubbing back should be avoided, for the resulting crop of

vigorous sprouts only complicates the problem. Mechanically weak growth should be removed early, in order to eliminate causes of breakage.

Little or no heading back should be given young trees. In cases where a head is not naturally formed low enough, cutting back may be necessary. Examination of the trunk of a young tree will reveal several cycles of growth, each terminated by a series of dormant buds. The cut should be made just above the strongest of these buds, which on starting usually makes an upright growth. The practice of heading back to laterals with the hope of developing one of these into a head has not been successful. In some of the weaker-growing types, shortening in to strong buds has been reported successfull in strengthening the stock and frame work of the trees while young. Severe cutting back of young trees accentuates the vegetative tendency and delays the fruiting period. Studies of evergreen trees in general indicate that larger size of tree and earlier bearing are favored by little or no pruning.

HARVESTING

With the varieties now grown in California, avocado fruits ripen every month in the year. Since the fruit will not soften on the tree and the external indications of maturity are often almost imperceptible, considerable difficulty is frequently experienced in determining the proper period for harvesting. With most of the dark-colored varieties this is usually not especially difficult, for by the time the skin is fairly well colored the fruits are ordinarily in proper condition for picking. There are exceptions, however, even in the dark-colored sorts. The difficulties are much greater with the green varieties, though it is usually possible for the experienced grower to detect slight changes in the color of the skin and stem as they approach maturity. The brightness of the skin color usually diminishes and a slight yellowish tint to both skin and stem often develops; there is, however, no safe and certain criterion of horticultural maturity except the laboratory determination for oil content.

The ripening seasons of the different varieties vary notably from season to season, and also differ widely in the different sections. The variation from season to season relates somewhat to weather conditions but is apparently affected even more by the setting period of the bloom, which is sometimes distributed over three or four months. Variation in the length of the period elapsing between bloom and maturity in the different sections appears to be related to differences in the amounts of heat during the growing season. In general, the

hotter, interior districts have more clearly defined seasons—shorter blooming and ripening periods—than the coastal districts. On account of the much longer blooming period in the coastal regions—starting earlier and lasting much later—harvesting usually starts earlier and lasts much longer, even though the average length of the period between setting and ripening is greater.

In order to provide for uniformity in the maturity of the fruit at the time of harvesting and especially to prevent the sale of immature avocados, a practice which had become a menace to the industry, the California avocado growers in 1925 succeeded in having a state maturity standard of 8 per cent fat or oil content established. This action has been productive of very great benefit to the industry in that it has effectively eliminated immature fruit, mostly windfalls or stolen fruit, from the markets. It is generally felt that the standard is still too low for the Mexican and some of the Guatemalan varieties, as is evident from the fact that the requirements for the best grades of fruit (Calavo) marketed by the Calavo Growers of California are considerably higher. As further information is developed concerning the normal range of fat content of the different varieties it may become desirable to raise the standards. The refractometer method of oil determination has been found to be relatively accurate, and this method is now used almost exclusively.

The fruits are clipped from the trees in the same manner as lemons, double cutting being employed to insure that the stem is cut flush with the base of the fruit. They should never be pulled from the trees as the removal of the pedicel or "button" with most varieties is almost certain to result in decay. On account of the great tenderness of the fruit it must be handled most carefully. The use of small canvas picking bags or buckets is advised as a means of preventing bruising of the fruit. For tall trees picking appliances consisting of a bag and nipper mounted on a pole, of which there are several types on the market, are used.

FROST INJURY AND FROST PROTECTION

Owing to the newness of the industry, comparatively little is known about the treatment of frost-injured trees. Varieties differ widely in the degree to which they withstand low temperatures. After the severe cold weather of the winters of 1922 and 1925 numerous and detailed observations were made on the various degrees of injury. Many trees that lost all foliage but did not suffer injury to the framework parts recovered in a remarkably short time. New leaves were put and in some cases bloom, followed by a small set of fruit the same

season. The spraying of defoliated trees with whitewash immediately after the freeze apparently was of benefit in preventing sunburn. Subsequent observations have demonstated that pruning should be delayed until all dying-back has ceased; cuts can then be made with the certainty that the injured wood has been removed. The resulting vigorous shoots should be thinned somewhat, in order to direct growth into a smaller number of well-spaced, strong-growing limbs.

Because of the softness of the heartwood and the readiness with which it decays, large frost cracks and injured areas should be carefully cleaned, disinfected with mercuric chloride (corrosive sublimate) or mercuric-cyanide solution of a strength of 1:1000, and later painted over with a waterproof covering such as asphaltum roofing paint, grafting wax, or bitutect. Special attention should be given such wounds, because decay sets in readily and spreads rapidly. If large areas of bark and wood are killed it is a question whether or not the resulting mechanical weakness can ever be overcome sufficiently to make a satisfactory tree.

Frost injury may be classified under three divisions: injury to the blossoms, injury to the fruit, and injury to the tree itself. The Mexican varieties bloom during the winter and are thus especially subject to frost injury with the resulting loss of the crop, even though the trees themselves may not suffer. The Guatemalan varieties, on account of their later blooming period, are somewhat less subject to loss of crop from frost injury. The development of varieties which bloom after the frost and mature their crops in eight to ten months will materially reduce losses. Several such new varieties are now under observation.

Because of its high oil content the ripe avocado fruit often escapes injury when the blossoms and tender growth are badly damaged. Heavy losses have occurred, however, from the freezing of the fruit stems, causing the fruit to drop. When the fruit itself is affected the first indication is usually the development of a reddish-brown color; the thinner-skinned varieties sometimes exhibit brownish-black spots. The first internal indication of frost injury is darkening of the fibers in the flesh, which usually turn black. The flesh may also turn gray in color and if badly frozen it fails to soften. After a period of damaging low temperatures it is best to discontinue picking for several weeks until the full extent of the injury is apparent. The damaged fruit can then be picked and thrown away or allowed to remain until it drops, as it usually does within a few weeks.

Frost injury to the tree itself may vary from the killing of the young tender growth to the killing of the tree down to the ground.

Aside from variety, the degree of injury depends largely upon the physiological condition of the tree. In general, trees maintained under optimum growing conditions enter the winter in the best condition to withstand cold. The maintenance of ample soil moisture is especially conducive to frost resistance. Trees weakened from insufficient moisture are invariably less resistant and suffer more. The withholding of water during the fall, supposedly to harden off the trees, cannot be recommended as a sound practice. Trees thus handled are ready to start into growth at the first rain which may occur in the early winter, and are in susceptible condition for frost injury. The best recommendation that can be made is to maintain favorable soil moisture conditions throughout the entire year.

There is a pronounced difference in frost resistance among the three races of avocados. The West Indian race is much too tender for planting in California with the exception of a few favored localities, and even there has rarely produced satisfactory fruits. Studies on the relative freezing points of the cell sap of the different races show that the sap of this race freezes at higher temperatures than do those of the Guatemalan and Mexican varieties. Of these two, the Guatemalan is the tenderer.[6] Prior to the freeze of 1922 it was generally believed that the Guatemalan race was as hardy as the lemon, and the Mexican as frost resistant as the orange. It is evident from many observations made after this and subsequent freezes, that the Guatemalan varieties must be considered for the most part somewhat more tender than the lemon. Mexican varieties, on the other hand, were observed in some localities to be less injured than neighboring orange trees, while in other localities they were somewhat more injured. Several varieties have proved to be outstandingly resistant where grown under good cultural conditions. These include the Northrop, Ganter, and Puebla, thin-skinned Mexican varieties; and the Fuerte and Dorothea, Guatemalan varieties which are apparently hybrids of Mexican parentage.

The behavior of these and of varieties of the Mexican race in general lends weight to the belief that varieties of the latter race may play an important part in the development of the commercial varieties of the future. It is certain that they merit more attention than has been accorded them in the past.

In an industry that promises such favorable returns, frost protection deserves more attention than it has received. With the exception

[6] Harris, J. Arthur, and Wilson Popenoe. Freezing point lowering of the leaf sap of the horticultural types of *Persea americana*. Jour. Agr. Research 7:261–268. 1916.

of the higher hillside plantings, most of the avocado orchards are subject to periodic freezing temperatures. The loss of the fruit is often of less consequence than the injury to the trees. Adequate frost protection must be considered a necessary feature of the orchard-management program. In a very limited way various methods of protection have been used, including plantings under lath, growing under tobacco cloth, and orchard heating. Of these only the last has proved satisfactory. Heaters of large fuel capacity, sufficient to withstand several days of cold weather, are necessary. A heater to each tree will doubtless prove advisable.[7]

WIND DAMAGE

The avocado is especially subject to wind injury, for which reason in the selection of planting areas it is important to avoid windy localities and sites as far as possible. Several types of injury may occur, according to the character of the wind and the season of the year. In the coastal areas the chilling effect of the cool summer ocean breezes is especially noticeable in retarding the growth of young trees, and the value of wind protection there has been definitely established. Strong winds of either the prevailing or occasional type are especially injurious to the fruit, and, according to its stage of development, either scar or bruise it, or break the stems and cause it to fall. Sudden windstorms during the fall months, which occur occasionally in nearly all sections, often cause important losses from the dropping and bruising of the nearly ripe fruit. Hot dry winds during the blooming and setting period are also unfavorable to a satisfactory set of fruit.

The prevention of wind damage, which is practicable in large measure, involves two principal considerations: the maintenance of favorable moisture and nutritional conditions in the trees and the use of screens or windbreaks of various kinds. Trees weakened from lack of water or starved for nutrients are noticeably much worse injured than normal vigorous trees. The benefits of favorable moisture and nutritional conditions in relation to the effect of hot dry winds during the blooming and fruit-setting period have frequently been observed. Trees neither over nor underirrigated and well supplied with available nitrates appear to exhibit much greater resistance to influences unfavorable to the fruit-setting process than do trees in less favorable condition.

Protection against chilling ocean breezes is usually afforded by the use of lath or burlap screens or windbreaks. Lath or board screens

[7] See: Schoonover, Warren R., Robert W. Hodgson, and Floyd D. Young. Frost protection in California orchards. California Agr. Ext. Cir. 40:1–73. 1930.

have been used to some extent for the protection of individual large and valuable trees (see fig. 2) and also for commercial plantings, but they are, of course, expensive. The most practicable mechanical means of wind protection consists of living windbreaks composed of closely planted trees of suitable characteristics. Among the most used windbreak materials are the blue gum eucalyptus (*Eucalyptus globulus*) and the Monterey and Arizona cypresses (*Cupressus macrocarpa* and C. arizonica). The former appears to be better adapted to the coastal regions than to interior districts; the latter does well in both. The athel (*Tamarisk articulata*) makes an unusually rapid growth in regions of warm summers but grows much more slowly in the coastal belt. Whatever material the windbreak may consist of, it is necessary that it be given proper management, which includes both irrigation and fertilization and periodic root pruning. These are necessary to maintain the windbreak in good condition of vigor and growth and still reduce to the minimum its competition with the adjacent orchard trees.

INSECT PESTS AND DISEASES

The avocado in California has been remarkably free from serious insect pests and, until recently, from important diseases. It was apparently introduced free from these hindrances, and some years have been required for insects and diseases already established in California to adapt themselves to the avocado, a new host plant. From this point of view the insect and disease-control problems may be expected to become increasingly important in the future.

Among the scale insects which occasionally infest the trees are the black scale, *Saissetia olea* (Bernard), the citrus red scale, *Chrysomphalus aurantii* (Maskell), the Spanish red scale, *Chrysomphalus dictospermi* (Morgan), and mealybugs, *Pseudococcus* spp. The usual control methods employed for these pests is the use of oil sprays. The control of mealybugs is dependant to a large degree on the control of the attending ants and the use of predacious and parasitic insect enemies.[8]

Of the other insects[9] perhaps the most important are the bean thrips, *Heliothrips fasciatus* (Pergande), and the greenhouse thrips, *Heliothrips balmorrhoidalis* (Bouche), which infest the fruit and foliage, causing serious scarring, cracking, and discoloration. They

[8] Borden, Arthur D. Control of the common mealybug on citrus in California. U. S. Dept. Agr. Farmers' Bul. 1309:1–10. 1923.

[9] Condit, I. J. Insect pests of the avocado. California State Comm. Hort. Monthly Bul. 8(1):27–29. 1919.

have been most injurious in the coastal areas, but also occur generally through the southern part of the state. Dusting with a 5 per cent nicotine dust or sulfur spraying with 2 per cent lime-sulfur will give control.

The branch and twig borer, *Polycaon confertus* (Leconte), frequently bores smooth, round holes, ⅛ inch in diameter and ¼ to ½ inch long in the bud axils or in the forks of the branches. The exuding sap, collecting in the burrows, evaporates and produces white powdery masses over the entrances, effectively concealing them. This beetle occurs throughout the avocado-growing districts of the state but is seldom sufficiently numerous to cause serious damage.

The fruit-tree serica, *Serica alternata* (Leconte), is sometimes responsible for the defoliation of the trees. It is most likely to be injurious in new plantings surrounded by uncleared land. Spraying with lead arsenate is the control measure employed.

A number of fungus diseases of the avocado have been reported, two of which attack the trunk or roots, and several which affect the fruit. A root disease[10] is caused by a species of *Pythiacystis*, similar to *P. citrophthora*, which causes a dying of the bark, indicated by black areas from which small beads of gum appear, followed by the deposition on the surface of a white powdery substance. Conditions favorable for its development are excessive moisture and poor drainage, most commonly found in lath-houses. The disease is not at all serious, though occasionally large trees may be attacked. Cutting out all affected tissues and disinfecting with Bordeaux paste has proved a successful control measure. It was formerly believed that the avocado was immune to attacks of the oak root or toadstool fungus, *Armillaria mellea*, but within recent years a number of cases of this disease on the avocado have been reported (fig. 18). No entirely satisfactory treatment is known, although careful cutting out of all the diseased tissues followed by thorough disinfection appears to materially retard its development.

In recent years diseases affecting the fruit have increased greatly in seriousness, and it is now apparent that unless control measures are developed for these diseases avocado growers must expect heavy losses in some seasons. Various fungi and at least one pathogenic bacterium, that producing citrus blast and black pit of the lemon, have been isolated from avocados decaying while still on the trees. The effect of some of these organisms appears to be confined to crack-

[10] Fawcett, H. S. A bark disease of avocado trees. California Avocado Assn. Ann. Rept. 1916:152. 1917.

ing and splitting of the skin, while others seem also to attack the flesh of the fruit. It is highly important that losses from these causes be prevented in so far as it is possible to do so, but their prevention must await the results of investigations now under way. From a packing-house point of view the worst of these diseases are anthracnose and a *Diplodia* spotting which sometimes pass through the packing house undetected, only to show up on arrival in the markets.



Fig. 18.—Mycelial growth of oak root fungus on an avocado trunk.

Some varieties, notably the Challenge and Puebla, seem also to be affected by a type of physiological breakdown which starts at the blossom or apical end of the fruit and sometimes causes serious losses.

Ever since avocado trees have been grown in California a burning and dying-back of the leaf tips has been noted, which has come to be known popularly as tipburn. All varieties appear to be affected, but

the degree to which this condition occurs varies greatly in different seasons and in different localities. Although tipburn may be induced by excessive transpiration during hot or dry weather, Haas[11] has shown that even in the coastal sections, where it is most prevalent, this condition is nearly always associated with an excessive chlorine content in the leaf ash. It appears therefore that the avocado tree is especially sensitive to this element, which under certain conditions accumulates in the leaves and causes dying-back from the tips. Obviously the source of the chlorine may be the content of the soil itself or the irrigation water or other substances containing chlorine which are applied to the soil. Whatever the source may be, it is clear that the prevention of this trouble, which, it should be said, is rarely serious, consists in the use of pure irrigation water, the provision of good drainage, and the employment of an annual leaching irrigation during the winter months.

In recent years there has been noted a rather widespread, yet apparently not infectious, condition of disease affecting avocado trees, known popularly as sun-blotch.[12] Trees or branches affected with this disturbance exhibit a pronounced pendulous or weeping habit of growth with a rough and scaly condition of the older bark and yellowish or light-colored and depressed streaks or strips on twigs and young branches. The fruits on diseased branches are also affected and exhibit irregular sunken areas of white, yellow or reddish color, often accompanied by dwarfing or distortion of the shape. Trees or branches affected are markedly dwarfed and fail to grow or fruit satisfactorily. The appearance of affected branches and fruits often resembles that resulting from severe sunburn, in other cases is markedly similar to variegated types of plant chimeras.

The cause is as yet unknown but many of the growers regard the disease as an effect of exposure to sunburn, since the protected parts of the tree rarely if ever show this condition. The effect, whatever the cause may be, appears to be permanent; the affected parts do not recover and the subsequent growth and crops are likewise affected. The theory has been advanced that this condition is a true chimeric effect produced as the result of pronounced sunburn.

In any event it is undoubtedly to be recommended that trees exhibiting this condition be avoided as sources of budwood or scion wood for propagation purposes. Should the theory as to cause prove

[11] Haas, A. R. C. Composition of avocado trees in relation to chlorosis and tipburn. Bot. Gaz. **87**:422–430. 1929.

[12] Coit, J. Eliot. Sun-blotch of the avocado. California Avocado Assn. Ann. Rept. **1928**:27–29. 5 illus. 1928.

correct, which remains to be demonstrated, appropriate methods of control would appear to consist first in the employment of measures designed to prevent sunburn, such as low heading, whitewashing, and shading, and second in pruning out the affected portions of the trees.

SOME FACTORS AFFECTING THE SETTING OF SATISFACTORY CROPS

Under apparently favorable environmental and cultural conditions, it is not uncommon for avocado trees to fail to bear satisfactory crops. This behavior is especially prevalent with the Guatemalan varieties in the interior districts, where it often constitutes the principal deterrent to success. Even though bloom may be produced in abundance, the young fruits very commonly fail to set, or in the event of setting, drop off before development proceeds very far. On the other hand, many seedling trees and some budded trees have failed to bloom regularly, even though well past the usual bearing age. Moreover, in most varieties there is a decided tendency to alternate bearing. The causes for these unsatisfactory conditions are not well understood, but there appear to be a number of factors involved in this behavior.

Alternate Bearing.—A marked tendency of the avocado to alternate bearing, especially with the Guatemalan varieties, has been reported in practically every region of the world in which this fruit is grown, including what is presumably its native habitat, Central America. This tendency is apparently accentuated in this state, where the experience for the past decade or more has been the alternate production of heavier and lighter crops, at times varying from a very large crop to almost a crop failure. The reasons for this behavior are as yet unknown, but certain observations furnish evidence to support the belief that the two principal factors involved are the nutritional condition of the trees at the time of bloom and the weather conditions which prevail during the blooming and setting period.

Thus it is commonly observed that after years of heavy production the trees which bore most heavily either exhibit a small amount of bloom or fail to bloom at all. Moreover, even though favorable weather conditions obtain during the setting period after a large-crop season it is well known that only a small set results, while if the weather conditions are severe, as during the 1929 season, the result is practically a crop failure. These observations all point to a lowered state of nutritional vigor in the trees induced by the heavy crop of the previous season. Further support for this belief is afforded by the observations that heavy spring applications of nitrogen in some light-

crop seasons apparently assist the trees in setting better crops, and that heavy and early thinning of the flower clusters and young fruits has, in several cases, apparently produced similar results. These observations considered in relation to the well-known facts that the avocado tree normally blooms much more profusely than most fruit trees and that the flowers are notably high in nitrogen content all support the conclusion, as yet undemonstrated however, that the drain of the crop during heavy crop years exhausts the trees to such a degree that during the following season they are unable to set and mature large crops. The occurrence of this phenomenon in other fruit trees is not unknown; it has been demonstrated with the apple in those districts where alternate heavy and light cropping is the rule, and field observations and trials indicate that it occurs in the olive in this state and in all probability elsewhere. Moreover it seems to obtain in the Valencia orange in California.

Until experimental data are forthcoming the most promising means of overcoming the alternate bearing habit of the avocado would seem to include the application of extra amounts of quickly available nitrogen in the springs of the light crop seasons coupled with heavy flower cluster and fruit thinning in the heavy crop years.

Weather Conditions during the Setting Period.—Other things being equal there can be little question that weather conditions during the fruit-setting period exercise a predominant influence on the set of fruit and hence the amount of crop produced. If the weather is unusually hot or dry during this period, or if it changes suddenly from moderate to extreme, abscission or shedding of a considerable part of the young fruits invariably occurs. If excessive in amount, this shedding is popularly referred to as the June drop. This phenomenon is especially important in the Washington Navel orange, a variety which is especially sensitive to abscission stimuli during the setting period. Coit and Hodgson[13] have shown that the initiating factor in the case of the orange is marked and rapid fluctuation in the moisture content of the young fruits, induced by excessive evaporation from the leaves. In all probability this same phenomenon occurs in the avocado and with a similar result, namely, abscission of the fruits.

The most promising means of prevention found thus far have to do first with encouraging the trees to bloom early and set the fruit before the normal advent of warm weather, and second with maintaining favorable moisture and nutritional conditions in the trees. The

[13] Coit, J. Eliot, and R. W. Hodgson. An investigation of the abnormal shedding of young fruits of the Washington Navel orange. Univ. of California Publ. in Agr. Sciences 3:283–368. 1919.

former is promoted by withholding irrigation water in the spring and thus permitting the soil to warm up and root action to start, the latter by the application of quickly available nitrogenous fertilizers in early spring. In seasons of late spring rains or cool weather extending to late in the season, such as occurred in 1929, there is little that can be done to encourage early blooming and if, as occurred that season, the weather suddenly turns very hot during the setting period, there is certain to be a very heavy drop of fruit.

For a satisfactory understanding of the effect of weather conditions on fruit setting in the avocado it is necessary to recall what has been stated concerning the alternate-bearing tendency of this fruit. If favorable weather occurs during the setting period of a normally heavy-crop year, as was the case in 1928, the result is a 'bumper' crop. If unfavorable weather occurs during such a season the result is a fair to good crop. If favorable weather occurs during the setting period of a normally light-crop year the result is a fair crop. If unfavorable weather occurs during such a year the result is a crop ranging from practically nothing, if the weather is severe, to a light crop.

Pollination.—Several investigators, from the results of their studies of flower behavior in the avocado, have advanced the belief that lack of opportunity for pollination is often the chief factor concerned in the failure to set satisfactory crops. Nirody[14] first called attention to the fact that the avocado flower normally exhibits dichogamy, in that the pistil matures before the stamens begin to discharge pollen. He also pointed out that the alternate development of the sex organs is decidedly synchronous for the tree as a whole and concluded that cross pollination was therefore essential for the setting of much fruit. Stout,[15, 16, 17] first in California and later in Florida, has also studied this phenomenon and has shown that the dichogamy exhibited is much more pronounced than Nirody reports, in that the flowers normally have two distinct periods of opening instead of one. He was also able to group all the varieties studied into two reciprocal classes with reference to the periods of flower opening, the two groups appar-

[14] Nirody, B. S. Investigations in avocado breeding. California Avocado Assn. Ann. Rept. 1922:65–78. 1923.

[15] Stout, A. B. A study in cross-pollination of avocados in California. New York Botanical Garden Contribution 251:29–45. 1923. Also in California Avocado Assn. Ann. Rept. 1922:29–45. 1923.

[16] Stout, A. B. The flower mechanism of avocados with reference to pollination and the production of fruit. Jour. New York Bot. Garden 25(289):1–9. 1924.

[17] Stout, A. B. The flower behavior of avocados. Memoirs New York Bot. Garden 7:145–203. 1927.

ently furnishing provision for the normal requirement of cross pollination. He showed further that weather conditions markedly affect the periods of flower opening and the degree of overlapping of these periods. Stout's findings were later confirmed by Robinson and Savage,[18] who reached a similar conclusion with reference to the desirability of mixing varieties of the two groups in order to insure for satisfactory cross pollination. The conclusions of these investigators may be summarized in the following statements:

1. Under bright clear weather conditions avocado flowers exhibit a marked tendency to open and close in unison and to open and close for two distinct periods at different times during the twenty-four hours.

2. The pistil is almost always receptive only during the first period of opening; during the second period the pollen is shed.

3. In most varieties under normal weather conditions there is little overlapping of the two opening periods, only a few of the flowers being open for the first time (pistil receptive) when flowers opening for the second time are shedding pollen.

4. All the varieties thus far studied can be placed in two groups with reference to the normal time and sequence of the opening and closing periods: one group (*A*) exhibits the first opening, during which the pistil is receptive but pollen not discharged, in the forenoon; the other (*B*) opens for the first time in the afternoon. In both groups a second opening of the flowers occurs, at which time the pistil is no longer receptive but the pollen is shed. The intervening period of eighteen to thirty-six hours separates the time of maturity of the sex organs in each flower.

5. Weather canditions exercise a marked influence on both the time and periodicity of the flower openings; this periodicity is most marked in bright clear warm weather; it is least pronounced in cool cloudy weather.

More recently H. van Elden, a graduate student in the College of Agriculture, has apparently demonstrated that pollination is normally effected at the first flower opening, since he has shown that with the Guatemalan and Mexican varieties the egg apparatus of the ovule is fully developed and ready for fertilization at that stage. He has also demonstrated a few cases of actual fertilization of the egg cell at the first flower-opening stage.

[18] Robinson, T. R., and E. M. Savage. Pollination of the avocado. U. S. Dept. Agr. Dept. Circ. 387:1–16. 1926.

Although the facts above given would indicate that under normal weather conditions self or close pollination of the avocado is either precluded or decidedly limited and that the normal requirement is cross pollination, Clark[19, 20, 21] has reported data which cast considerable doubt on the validity of this conclusion. He first demonstrated that the common honey bee is the insect chiefly concerned with effecting pollination and later established the fact, at least for the mild southern coastal region, that most avocado varieties are partially or entirely self-fertile and will set satisfactory crops without cross pollination, provided bees are active during the period of bloom. He has presented some evidence that with the Dickinson variety cross pollination is somewhat more effective than self pollination, a condition which he did not find in any of the other varieties studied. On the basis of his studies he concludes that provision for cross pollination is of doubtful value, with some possible exceptions, but that the presence of bees during the blooming period is necessary for the setting of good crops.

Observations in other avocado-producing sections tend to support his conclusions in that there are numerous cases where cross pollination is precluded yet in some seasons at least satisfactory crops have been produced. Apparently there is usually sufficient overlapping of the opening periods of the flowers, or else bees are able to affect pollination either by carrying the pollen from one opening period to the next or by penetrating the opening or closed flowers. On the basis of the present evidence we may conclude, therefore, that the necessity for or benefits of cross pollination of the avocado in California have not yet been demonstrated, although there is still much experimental work to be done before all the facts will be known.

For the benefit of those who wish to make provision for cross pollination by planting or topworking varieties of different blooming habits the following lists are given. The determinations are based on the work of Stout and Robinson and Savage. The varieties in group *A* normally are receptive to pollination during the forenoon; those in group *B* in the afternoon. Group *A* varieties normally discharge pollen in the afternoon; those in group *B* in the forenoon. Varieties marked (G) are of the Guatemalan race; those (M) of the Mexican; those marked (W) West Indian; and those (H) presumably of hybrid origin.

[19] Clark, O. I. Avocado pollination and bees. California Avocado Assn. Ann. Rept. **1922–23**:57–62. 1923.

[20] Clark, O. I. Avocado pollination tests. California Avocado Assn. Ann. Rept. **1923–24**:16–22. 1924.

[21] Clark, O. I., and A. B. Clark. Results of pollination and other experiments at Point Loma. California Avocado Assn. Ann. Rept. **1925–26**:85–95. 1926.

GROUP *A*

Atlixco (G)	Gottfried (M)	Puebla (M)
Benik (G)	Grande (G)	Sharpless (G)
Blakeman (G)	Hawaii (W)	Simmonds (W)
Butler (W)	Ishkal (G)	Sinaloa (G)
Cantel (G)	Kashlan (G)	Solano (G)
Challenge (G)	Lula (H)	Spinks (G)
Clower (G)	Manik (G)	Taft (G)
Collinson (H)	Mayapan (G)	Taylor (G)
Colorado (G)	Murrieta (G)	Ultimate (G)
Dickey (G)	Pankay (G)	Wagner (G)
Dickinson (G)	Perfecto (G)	Waldin (W)

GROUP *B*

Cabnal (G)	Lamat (G)	San Sebastian (M)
Champion (G)	Linda (G)	Schmidt (G)
Colla (G)	Lyon (G)	Stephens Choice (G)
Collins (G)	Macdonald (G)	Surprise (G)
Dorothea (H)	Meserve (G)	Tertoh (G)
Eagle Rock (G)	Montezuma (G)	Trapp (W)
El Oro (G)	Nabal (G)	Tumin (G)
Fuerte (H)	Nimlioh (G)	Val de Flor (M)
Ganter (M)	Northrop (M)	Verde (G)
Harman (M)	Panchoy (G)	Walker (G)
Ishim (G)	Pollock (W)	Winslow (G)
Itzamna (G)	Queen (G)	Winslowson (H)
Knight (G)	Rey (G)	

Girdling.—Girdling has been resorted to as a means of stimulating fruit production on otherwise barren trees. Successful results have been obtained in some cases and in others none whatever. The Taft variety, which has been conspicuous for its delay in coming into bearing, has been the object of such experimentation more than any other. A number of growers have succeeded in getting fruit to set in abundance on girdled limbs while the rest of the tree failed to produce. Girdling is best done in October. A ring of bark varying from ⅛ to ¼ inch in width is removed, usually near the base of the limb; a ring of this size will readily heal over. Apparently the downward flow of sap is checked and the storage of food materials stimulates fruit production. Girdling is still largely in the experimental stage, however, and cannot be considered as the solution of the many-sided problem of rendering barren trees fruitful. It has the disadvantage of lowering the resistance to frost of the limb girdled, and of weakening the roots through subjecting them to a period of partial starvation.

Bud Selection.—Several cases of bud sports in the avocado have been reported; the possibility therefore exists of their being important in connection with the problem of low production. Thus black Ganter fruits are consistently produced on one limb of a large tree in Whittier. And there appear to be two rather distinct types of the Fuerte, the standard and a round sort; the latter may have occurred as a bud sport. Thus far no sports showing decreased yield have been reported in the avocado. Sports of this kind occur commonly in the citrus fruits and in the past their unintentional propagation has resulted in thousands of low-yielding or 'boarder' trees. The fact that they have not been reported in the avocado does not necessarily mean that they do not or will not occur in this fruit. Certain it is that the greatest possible care should be exercised in the selection of budwood. If possible it should be taken only from healthy bearing trees of known record both as to yield and desirable fruit quality.

MARKETING

Avocado production in California did not reach the point where marketing problems became acute until comparatively recently. Prior to that time production was relatively so small that the local markets were able to absorb the crop at very satisfactory prices. Price levels were in fact too high to favor any appreciable extension in the use of the fruit. These high prices, however, greatly stimulated the planting of avocado orchards; some years ago it became evident that the time was not far removed when production would increase so greatly as to render it necessary for the growers to concern themselves with marketing problems.

In anticipation of this situation the California Avocado Association early undertook a study of the marketing problem, with the result that in 1921 an arrangement was made whereby the fruit was marketed through a large fruit and vegetable marketing agency with selling agents in many of the principal markets. The crop was handled on a commission basis, with the understanding that some effort would be made to introduce the fruit into new markets and to advertise it. The members reserved the right to market such fruit as they desired locally. This arrangement did not prove to be very satisfactory, and within a year or two the increase in production was such as to indicate the need for increased marketing facilities.

With the support and financial assistance of the California Avocado Association, the California Avocado Growers' Exchange, a cooperative marketing agency, was organized in February, 1924. In

1927 the name of this organization was changed to the Calavo Growers of California. The plan or organization followed was similar in many respects to that employed by the citrus growers in that the organization is a non-stock, non-profit, cooperative agency, with a board of directors composed of elected representatives from the principal avocado-producing districts and a limited number of directors elected at large. A centrally owned and managed packing house was established at Los Angeles, and more recently several additional houses have been established at other central points.

Considering the problems presented in introducing and popularizing a new and unique fruit, and the limited funds which have been available, this organization has been remarkably successful in marketing the crops of its members. The percentage of the crop it handles has increased greatly since the time of its organization, and it is at the present time by all odds the dominant factor in the California avocado industry. It had scarcely been organized when the expected increase in production materialized and the necessity arose of immediately developing outlets for the fruit in the markets of eastern United States. This has required costly and sustained effort on the part of the producers, but it was indeed fortunate that the organization was available for the task. While, necessarily, progress has been slow, it has been able to extend the market outlets rapidly enough to absorb the surplus over the local requirements, which consists mainly of the markets in Los Angeles and San Francisco. As a consequence price levels have continued to be relatively high, much higher in fact than can probably be expected in the future, when the production is several times what it is at present.

Certain of the problems presented in the successful marketing of avocados are worthy of special mention since they either are associated with the unique characteristics of the fruit or differ in other and important respects from the problems ordinarily encountered in marketing fruits. Among the former are the distinctive flavor of the fruit and the after-ripening or softening required before it is ready for consumption. The avocado is neither sweet nor acid in taste and exhibits a characteristic buttery consistency and flavor when ready for consumption, both of which are usually unexpected and consequently sources of surprise to the person unacquainted with this fruit. To some the taste is at first disappointing but with most the liking for it is easily and quickly acquired. Even though fully mature when picked the avocado must undergo softening before it becomes palatable and ready for consumption. If picked immature the flesh remains hard and tough and the laurel or anise flavor and odor characteristic

of the tree persists. If held to the point where the fruit becomes overripe the color of the flesh darkens and objectionable flavors and odors develop. Yet the properly matured and softened fruit is so delicious as to rapidly develop in most palates a lasting taste for it. To introduce this new and distinctively different fruit and insure that it is handled in such a way that it reaches the consumer in proper condition for consumption has required a tremendous amount of educational effort. The measures employed in this work have included demonstrations at which the fruit is served, the use of window displays, the distribution of recipe booklets and bags on which directions for the use of the fruit are printed, and extensive publicity and advertising.

Among the difficult merchandising problems presented in the marketing of the avocado have been those relating to picking, packing, transportation, and storage of the fruit, all of which had to be learned by experience, and successful distribution and sale of a rapidly increasing, yet widely fluctuating, volume of product. The increase in production in some seasons has been many hundredfold, only to be followed by a short-crop year with the attendant difficulty of supplying the demand previously created. There has also existed the problem of meeting the low price and inferior-quality competition of Cuban avocados, imported in large quantities, and the widely fluctuating competition of the Florida avocado industry. Considering the variety and scope of the problems presented, the cooperative marketing agency has thus far been phenomenally successful in its operations and most decidedly a great asset to the industry.

Through the efforts of this marketing agency, many important improvements have been brought about in the industry, such as the adoption of a legal minimum standard of maturity; the enforcement of laws against fruit stealing and the initiation of much needed investigations.

For the dual purpose of advertising California avocados and the brand of the marketing organization, the first-grade, mature fruits of selective varieties sold by the Calavo Growers of California are stamped with the word Calavo, the term being derived from the abbreviation and combination of the two words California and avocado. Other grades have also been established, and in all cases the grade is stamped on the fruit. Each grade has certain requirements as to size, color, freedom from blemishes, and fat content, the latter varying with the variety.

Before picking starts, samples are submitted to the laboratory which the organization maintains for testing the fruit for maturity. If the test is satisfactory permission to pick is granted, usually

accompanied with instructions as to the amount of fruit it is desirable to pick. The fruit is then picked, as previously described, and hauled to the nearest packing house. Especial care is taken to prevent bruising when it is placed in the picking boxes and to minimize the jolting incident to loading, hauling, and unloading. On receipt at the packing house the lot is given a packing number or designation, weighed, and placed in storage to await the proper condition for packing.

Fruit to be sold on the local markets is held in storage at room temperature until softened sufficiently for consumption. If storage for longer periods is required it is held in cold storage chambers at 40° to 45° Fahrenheit, experience having shown that the fruit keeps best in this temperature range. Under especially favorable conditions some varieties have been successfully stored for as long as two months, but this practice is not recommended and is possible only where the fruit is specially selected. Fruit to be shipped to eastern markets is pre-cooled for 48 hours at 40°–45° F and then shipped or stored under refrigeration. This class of fruit is sold in the firm condition, the wholesaler or retailer holding it until the proper stage for consumption is reached. In the past most of the shipments have been by express, though experience in recent years has shown that if properly handled the fruit ships satisfactorily under fast freight. During the past three years many carload shipments have been made in this manner. Shipments by steamboat via the Panama Canal have shown that the fruit successfully withstands the long trip, provided it is properly selected and prepared for treatment. Shipments have also been made successfully to foreign countries.

When ready for packing the fruit is run through automatic machines where it is cleaned and polished by means of revolving brushes and wipers. It is then graded by hand and placed in receptacles on a moving belt which carries it to the stampers. Each fruit is then stamped by hand with its proper grade (Calavo, Bueno, Fino, etc.). The graded and stamped fruits are then placed on a moving belt which leads to an automatic weight-sizer apparatus. As the belt travels along each fruit trips the proper counterbalance and drops into a padded bin. The graded, stamped, and sized fruits are packed from the bins by nesting in soft wood excelsior without wrapping. (fig. 19). The standard container employed by the cooperative agency is a one layer flat, which when packed weighs approximately 13½ pounds. A larger 'jumbo' container is used for extra large fruits. The number of fruits per flat is determined by the size and shape of the fruits and varies considerably. As with other fruits, the size designation employed denotes the number of fruits per box.



Fig. 19.—Interior view of Los Angeles packing house of Calavo Growers of California, showing grading and stamping (in the background), automatic weight-sizing, and packing (in the foreground).

In recent years shipment of the fruit to eastern markets, mainly Chicago and New York, has become of increasing importance as a means of relieving the local markets of surplus supplies, and the amount of the crop shipped out of the state has increased rapidly. Whereas a few years ago only a few hundred boxes of fruit were shipped to eastern markets, in the 1928–29 season a large part of the crop, amounting to several million pounds, was shipped out of the state.

HORTICULTURAL RACES

As previously indicated there are three general groups of avocados grown in the United States, for convenience loosely termed the West Indian, Guatemalan, and Mexican races, though not strictly separate horticultural races in the technical sense of the term. Of these three races, two only are of commercial importance in California—the Mexican and the Guatemalan. Popenoe[22] has classified these as follows:

1. Leaves anise-scented; skin of fruit thin (rarely more than 1/32 inch in thickness. *Persea drymifolia.* Mexican race.

2. Leaves not anise-scented; skin of fruit thicker (from 1/32 to 1/4 inch in thickness). *Persea americana.*

a. Fruit summer and fall ripening; skin usually not more than 1/16 inch thick, leathery in texture. West Indian race.

b. Fruit winter and spring ripening; skin 1/16 to 1/4 inch thick, woody in texture. Guatemalan race.

At least one variety intermediate in form between the Guatemalan and Mexican races has appeared—the Fuerte, an apparent hybrid between these two groups. The Dorothea is also thought to be a hybrid of this sort.

Hybrids between the Guatemalan and West Indian races are not uncommon and seem destined to play an important part in the Florida avocado industry. Among those considered most promising are the Winslowson, Collinson, Lula, and Simmonds.

The West Indian race is unsuited climatically to California conditions, as evidenced by the failure of the plantings made in the past, and may be disregarded as far as its economic importance in this state is concerned. Belonging as they do to different species, the important, outwardly-evident, botanical differences serve to differentiate the Guatemalan and Mexican races horticulturally. The leaves of the Mexican race are usually smaller than those of the Guatemalan, and are sharper at the apex. They have the characteristic anise odor

[22] Popenoe, Wilson. Manual of tropical and subtropical fruits, p. 66. The Macmillan Co., New York. 1920.

when crushed, which is entirely lacking in the Guatemalan race. This property is also characteristic of the immature Mexican fruits. The fruits of the Mexican race are smaller, rarely reaching a pound in weight, are smooth, dark green to purple in color, and often glossy. They mature usually from August to December—from nine to ten months after blooming. The seed is commonly larger in proportion to the edible part of the fruit than that of the Guatemalan. The two seed coats are thin, sometimes closely united and adhering to the cotyledons, and sometimes separating. The flowers appear during the winter and early spring, and are subject to frost injury in severe winters. Occasionally late flowers appear and furnish a light second crop in the early spring.

The fruit of the Guatemalan race is large, averaging from 12 to 20 ounces, some varieties attaining a weight of more than 3 pounds. It varies in color from green to purplish or reddish black. The surface, while sometimes fairly smooth, is usually rough and somewhat warty and coarsely granular in texture. The seed fits tightly into the cavity, its seed coats are thin, united, and adherent to the cotyledons throughout. The flowers appear later than those of the Mexican race, usually after most danger from frost is past. The fruit matures from twelve to eighteen months after the blossoming season.

Many varieties of both the Guatemalan and the Mexican groups are fruiting in California at the present time—the number exceeds two hundred. Because of their greater resistance to cold, the Mexican varieties enjoy a much wider range of adaptation.

CONSIDERATIONS RELATING TO CHOICE OF VARIETIES

In choosing varieties for commercial planting certain general characteristics are to be desired in both the tree and the fruit. The tree should be hardy, a vigorous grower, and a regular and heavy producer of fruit. It should be readily propagated and easily handled in the nursery. It should make good growth yet come into bearing at a reasonably early age. Varieties that come into bearing too early usually exhibit a tendency to expend their energies in flowering and bearing at the expense of tree development. The first few years of the life of any fruit tree should be primarily devoted to the building up of a strong tree capable of sustained production over a long period of years, rather than to the early production of fruit.

The length of time between blooming period and maturity is also an important consideration. Most of the thin-skinned fruits mature

from nine to twelve months after blooming; on the other hand few of the Guatemalans mature under fourteen months, some requiring from eighteen to twenty-two. Several of the newer Guatemalan varieties bloom in the spring and mature their fruit in the fall and winter of the same year. In developing new varieties this question is one that should receive consideration.

At the present time there is sufficient variation in season among the varieties in California to furnish ripe avocados for every month of the year. It would seem advisable, however, for the growers in the various avocado-producing sections to take advantage of the natural ripening seasons in their respective districts in so far as this is practicable. Thus, it would seem best for the growers in the early-ripening districts to grow largely the early-ripening varieties and for the growers in the late sections to concentrate mainly on the late varieties. For, obviously, an early-ripening variety grown in a late district is neither early nor late and consequently cannot possibly command any premium on this basis.

The market demands are important in considering the fruit itself. Thus far the market preference has clearly been for medium-sized fruits, weighing from 8 to 14 ounces, although there is a limited demand for large-fruited varieties. Color appears to be less important than size, though the green-fruited varieties are now much more in demand than the colored sorts. Whether these preferences are the result of the prevalance of supplies of varieties exhibiting these characteristics it is impossible to say. The importance of selecting and growing varieties which meet with favor in the markets, however, can hardly be overemphasized. The fruits should be as uniform in shape as possible and preferably broadly pyriform, oval, or round. The flesh should be thick and the seed small and tight in the cavity. The absence of fibre in the flesh is especially desirable. Extreme thickness and roughness of rind have proved to be undesirable characters, since they render it more difficult to determine when the fruit is ready for consumption.

California avocados must meet the competition of Florida and Cuban avocados, which ripen mainly during the summer and early fall months. The heavier supplies from these sources occur during the period July to November, which is exactly the season when avocados are scarcest in this state. From the competitive point of view, therefore, the best market period comprises the fall, winter, and spring months, and fortunately for the California grower this is the period which he can readily supply with the varieties now available. Owing to the fact that the competitive supplies are nearly altogether of the

West Indian varieties, there exists a demand for a limited supply of California Guatemalan fruits during the summer and fall months at prices which thus far have been prevailingly high. This has stimulated the search for late-ripening varieties and provides a decided advantage for those districts where climatic conditions favor lateness of maturity. According to the experience of recent years, price levels for California avocados are usually highest during the summer and fall months and lowest during the winter and spring months.

With the establishment of the avocado as an important article of food rather than a luxury, an all-year-round demand will be created. In the selection of varieties this condition should be taken into account. At the present time there is sufficient variation in the ripening periods of the varieties available and in the normal seasons of maturity in the sections where they can be grown to supply ripe avocados in some quantity every month in the year.

The place of the thin-skinned Mexican varieties in the industry is still problematical. The fruit is finer in flavor, and often in quality, than many of the larger Guatemalan fruits. They ripen early and if properly handled can be shipped satisfactorily, at least to the great central region. Objections to the small size of most varieties of this group can be overcome by developing or introducing varieties of larger size. A large-fruited variety, the Topa Topa, is now meeting with decided favor in the markets. The large-fruited varieties introduced by Popenoe from South America some years ago have failed to fruit satisfactorily in California. For local markets and regions nearby and for home use the Mexican varieties have a very definite place. They may prove to be even more valuable in the future than at present.

The matter of selecting varieties is one of considerable perplexity. The industry has been fortunate in its early history, in having an active growers' organization, the California Avocado Association, working in its interests. The Association early organized a Committee for the Registration and Classification of Varieties, whose duty it has been to study the behavior of the different varieties over a period of years and to make recommendations according to its observations. The lists of recommended varieties prepared by this committee afford the safest guide to planting at the present time. That these lists will be revised from time to time is certain; numerous changes have been made in the past as knowledge has been gained by experience. The commercial varieties of the future may be largely different from those of the present. But the recommendations offered represent the concensus of opinion of the best growers at the present time.

The history of avocado culture in California has been an almost continual procession of new varieties, as seedlings or introduced varieties have come into bearing and have been ardently promoted by their enthusiastic developers or introducers. Many varieties have been propagated and distributed prematurely. Others have been unwisely exploited before testing. The result is that there are many named varieties which have already been discarded and many more which should be and will be abandoned in the future.

Descriptions of the principal commercial varieties and of the most promising of the not yet proved varieties are given below. Allowance should be made for normal variation in the size of the fruit and in the ripening season, which differs markedly in different sections.

RECOMMENDED COMMERCIAL VARIETIES

Fuerte (fig. 20).—At the present time this is the only variety considered worthy of unqualified recommendation for commercial planting. Form pyriform (not necked) to oblong; size below medium to above medium, 8 to 12 ounces, length 4 to 4½ inches, greatest breadth 2½ to 2⅞ inches; base pointed; the stem inserted obliquely in a small shallow cavity; apex obliquely flattened, depressed around the stigmatic point; surface pebbled, sometimes slightly wrinkled around the stem, dull green, with numerous small yellow dots; skin about 1/24 inch thick, separating readily from the flesh, pliable and leathery in texture; flesh rich cream yellow in color, greenish near the skin, of smooth, buttery texture, and very rich flavor; quality excellent; seed medium, tight in cavity, seed coats closely surrounding cotyledons. Season November to June in southern California. Fruit reaches a maximum of 25 to 30 per cent of oil. Fine flavor and quality.

This variety originated at Atlixco, State of Puebla, Mexico, and was introduced into California in 1911. The tree is unusually vigorous, hardy, and productive. Its season of ripening is exceptionally long. This variety and the Puebla described below were the two outstanding hardy varieties on the recommended list of the Avocado Association that emerged from the severe cold wave of 1922 with comparatively little injury. The Fuerte is apparently a natural hybrid between the Guatemalan and Mexican races, though final proof of this assumption is yet to be made. It partakes of the characteristics of both races.

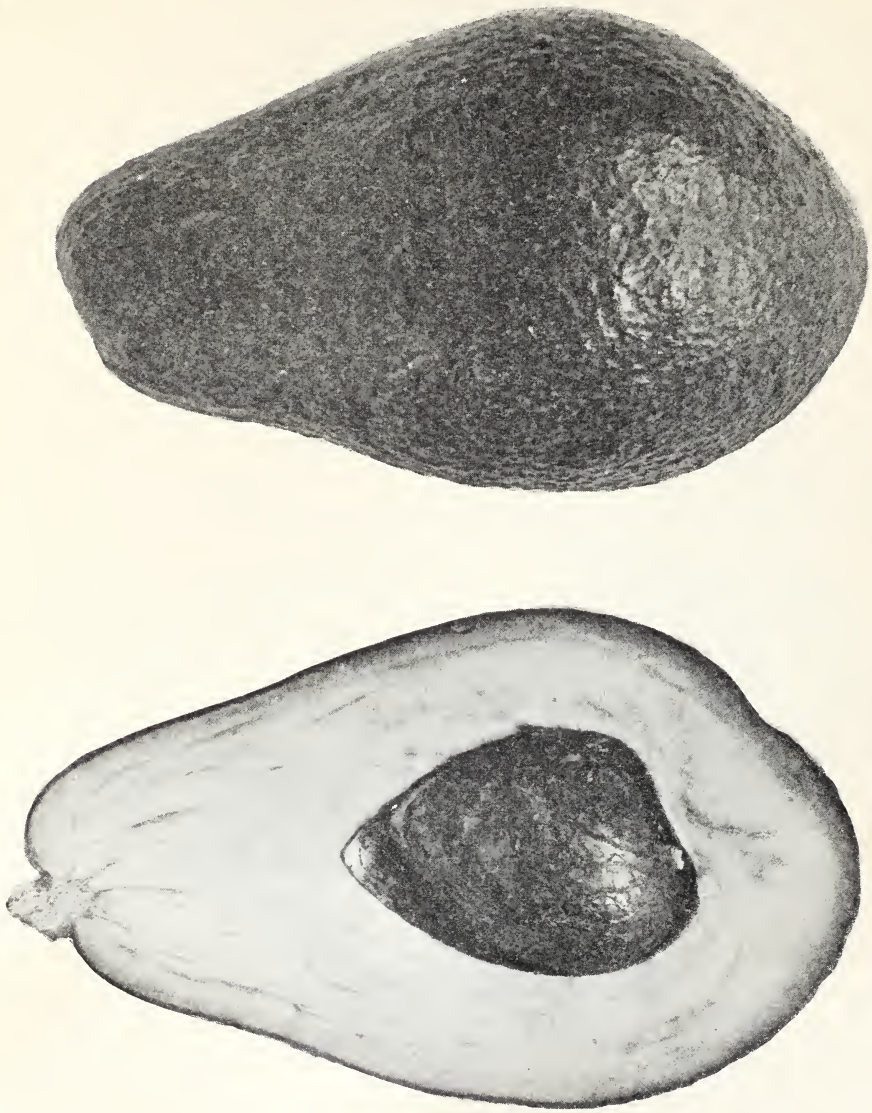


Fig. 20.—Fuerte, one of the best commercial varieties. See text for description. Two-thirds natural size. (From Bul. 365.)

VARIETIES OF MERIT, CANDIDATES FOR COMMERCIAL RATING

Puebla (fig. 21).—Form obovoid, slightly oblique; size below medium to medium, weight 5 to 12 ounces, length 3½ inches, greatest breadth 2⅞ inches; base obliquely flattened, the stem inserted slightly to one side in a small shallow cavity; apex obliquely flattened but not prominently so; surface smooth, glossy, deep maroon-purple in color, with numerous reddish dots; skin less than 1/32 inch thick, easily peeled from the flesh, firm in texture; flesh rich cream yellow near the seed, changing to pale green near the skin, buttery in texture, and of rich nutty flavor; quality very good, seed medium to large, tight in the cavity, with both seed coats adhering closely to the cotyledons. Oil content 18 to 28 per cent. Season December to February in southern California. Mexican race.

The Puebla originated at Atlixco, State of Puebla, Mexico, and was introduced and first propagated in California in 1911. The tree is exceptionally hardy and vigorous, and well balanced in form. It fruits later in the season than most others of the Mexican race.

Queen (fig. 22).—Fruit oblong-pyriform, large, 5½ inches long, weighing 1½ pounds; skin rough, deep purple in color, thick and woody; flesh rich clear yellow, dark green near skin, free from fiber; flavor rich, quality very good; seed very small and tight in cavity. Oil content 12 to 15 per cent. Season May to October. Guatemalan race.

The variety was introduced from the highlands of Guatemala by E. E. Knight. It is a vigorous but spreading grower, rather tender, and should be planted only in the warmest sections. The tree bears good crops, but has a decided tendency to alternate bearing.

Taft.—Fruit pyriform in shape; size medium, weight 14 to 24 ounces; skin medium in thickness, slightly rough, green. Seed medium. Flesh cream to golden yellow, flavor rich, quality excellent; fiber very slight. Oil content 16 to 20 per cent. Season May to November. Guatemalan race.

This variety originated on the place of C. P. Taft, Orange, California in 1900. The tree is very vigorous but is usually slow to come into bearing; this is the chief objection to this variety. It is especially adapted to the coastal districts.



Fig. 21.—Puebla, one of the best of the Mexican varieties. See text for description. Natural size. (From Bul. 365.)

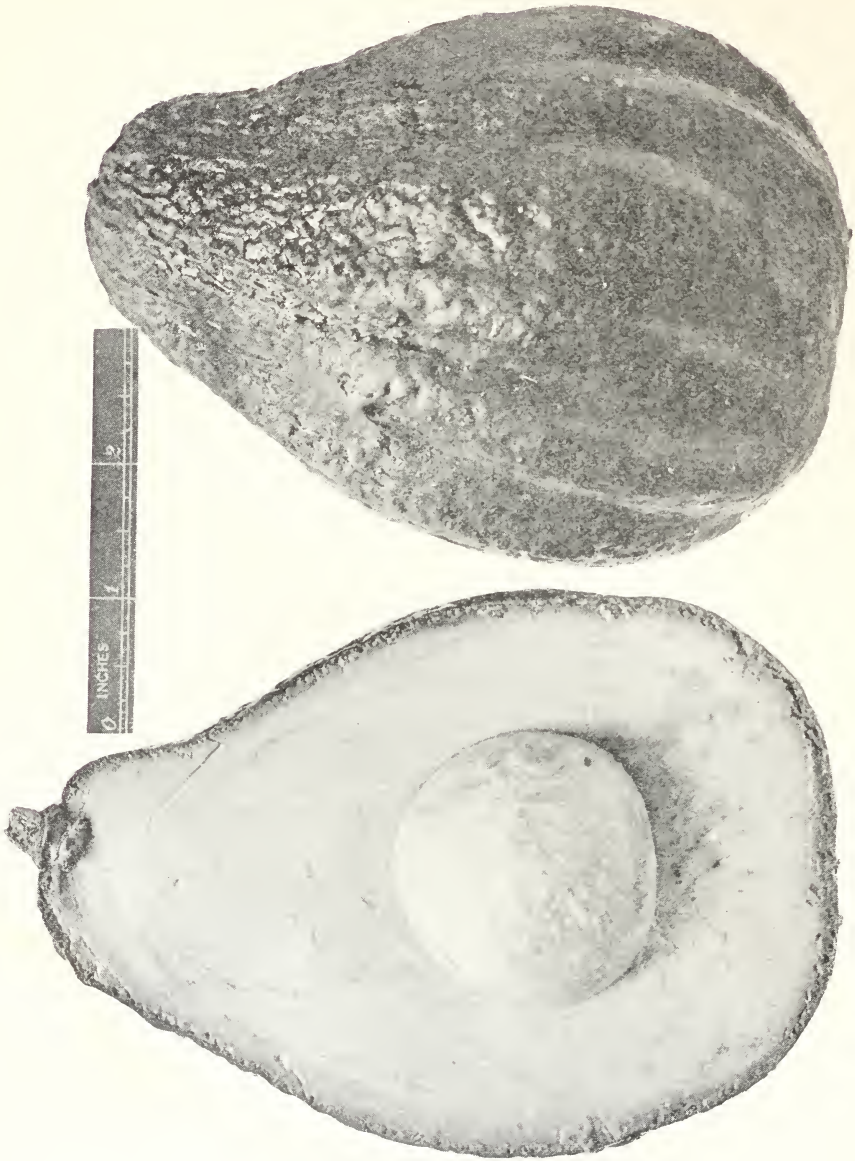


Fig. 22.—Queen, one of the best of the large-fruited Guatemalan varieties. See text for description. (From Bul. 365.)



Fig. 23.—Nabal, one of the most promising of the United States Department of Agriculture introductions. See text for description. (From Bul. 365.)

Nabal (fig. 23).—Number 15 of the United States Department of Agriculture introductions by Wilson Popenoe in 1917 from Antigua, Guatemala (S.P.I. No. 44439). Fruit almost round, weight 12 to 18 ounces, smooth, green. Seed rather small. Flavor exceptionally good and quality excellent. Oil content 12 to 15 per cent. Season June to September. Guatemalan race.

A good grower and a heavy and consistent bearer. This variety is undoubtedly one of the most promising of the Department of Agriculture introductions.

Anaheim (fig. 24).—Fruit oval to elliptical; size medium, 16 to 24 ounces; skin thick, rough, green, glossy. Seed medium to small. Oil content 15 to 18 per cent. Season June to September. Guatemalan race.

The variety originated near Anaheim. The tree is tall and slender and a prolific bearer.

Dickinson.—Fruit oval to almost pyriform; size small to medium, 9 to 16 ounces; skin very thick and very rough, dark purple. Seed small. Oil content 10 to 14 per cent. Season May to October. Guatemalan race.

The variety originated in Los Angeles about 1899. The tree is a good grower, vigorous, and a prolific bearer.

Mayapan (fig. 25).—Fruit nearly round, slightly corrugated, flattened; size medium, 12 to 18 ounces; skin very thick and rough, purple. Seed small. Oil content 16 to 20 per cent. Season May to August. Guatemalan race.

The variety was introduced by Wilson Popenoe from Guatemala as No. 23 (S.P.I. No. 44680). The tree is a good bearer.

VARIETIES SUGGESTED FOR AMATEURS' COLLECTONS AND EXPERIMENTAL PLANTINGS

Varieties marked with the asterisk (*) are especially recommended.

***Anaheim.**—Description given above.

***Benik.**—Introduced by Wilson Popenoe from Antigua, Guatemala as No. 21 in 1917 (S.P.I. No. 44626). Fruit pear-shaped; 20 ounces, rough, maroon-purple. Seed small. Season May to August. Guatemalan.

Cantel.—Another of the Wilson Popenoe introductions from Antigua. Number 28 (S.P.I. No. 44783). Fruit round, 16 ounces, surface pebbled, green. Seed very small. Season August and September. Guatemalan.



Fig. 24.—Anaheim, another promising variety. See text for description. (From Bul. 365.)

***Carlsbad.**—Probably identical to the old Stephens No. 2 at Montebello. Fruit pyriform, 16 ounces, smooth, mahogany-purple. Flavor very good. Prolific. Seed rather large. Season March to May. Guatemalan.

***Dickinson.**—Description given above.

***Duke.**—Originated at Sunnyslope nursery, near Wyandotte, California, in 1912. Fruit pyriform, 8 to 12 ounces, green. Seed generally tight in cavity. Season October and November. Mexican.

Dutton.—Originated at Anaheim in 1910. Fruit pyriform, 16 ounces, very rough, warty, dark maroon. Seed medium to small. Season February to April. Guatemalan.

***Fuerte.**—Description given above.

Ishim.—Introduced by Wilson Popenoe from Guatemala in 1917 as No. 34 (S.P.I. No. 45562). Fruit pear-shaped to obovoid, 8 to 12 ounces, smooth, deep maroon. Skin thin. Seed medium. Season January and February. Guatemalan.

Itzamna.—Introduced by Wilson Popenoe from Guatemala in 1917 (S.P.I. Nos. 43486 and 55736). Fruit oblong pyriform, 14 to 16 ounces, slightly rough, light green. Seed very small. Season June to November. Guatemalan.

Kashlan.—A Wilson Popenoe introduction from Guatemala, No. 10 (S.P.I. No. 43934). Fruit round or broadly oval; 20 ounces, smooth, green. Seed unusually small. Season May and June. Guatemalan.

Linda.—Introduced from Guatemala by E. E. Knight of Yorba Linda, California, as No. 29 in 1914. Fruit round to elliptical, large, 32 to 36 ounces, rough, deep purple. Seed medium. Season May to October. Guatemalan.

***Mayapan.**—Description given above.

Miller.—Seedling tree from Guatemala planted on Jacob Miller place, Hollywood, California, 1886. Fruit oval, 8 to 12 ounces, rough, green. Seed large. Season March to August. Guatemalan.

***Nabal.**—Description given above.

Northrop.—Originated on the old Northrop place near Tustin, California, about 1900. Fruit oblong-pyriform, 5 to 7 ounces, smooth, purple. Seed medium. Season October and November. Mexican.

Panchoy.—Introduced by Popenoe as No. 18 (S.P.I. No. 44625) from Guatemala. Fruit broadly obovoid, 20 to 30 ounces, rough, green. Skin thick; seed small. Season June to August. Guatemalan.

***Puebla.**—Description given above.

***Queen.**—Description given above.



Fig. 25.—Mayapan, another promising United States Department of Agriculture introduction. See text for description.

Sharpless.—Originated on B. H. Sharpless place near Tustin, California, 1901. Fruit slender pyriform, 16 to 24 ounces, somewhat rough, purple. Seed small to medium. Season May to October. Guatemalan.

***Stephens Choice.**—Sometimes known as Choice. Introduced from Atlixco, Mexico, by William Stephens of Montebello, California. Fruit slightly pyriform to round, 16 to 20 ounces, smooth, green. Seed medium to large. Season June to August. Guatemalan.

Taft.—Description given above.

***Thompson.**—Originated on place of Miss Jessie Thompson at Montebello, California, in 1913. Fruit long pyriform, 14 to 21 ounces, slightly pebbled, dark purple. Seed very small. Season March to June. Guatemalan.

Topa Topa (fig. 26).—Originated on old Thatcher place at Nordhoff, California, in 1907. Fruit oblique elongated pyriform, 6 to 10 ounces, glossy, purple. Seed medium. Season September to December. Mexican.

Worsham.—Originated at Whittier, California, in 1910. Fruit oblique oval, 12 to 14 ounces, smooth, green, glossy. Seed medium to large. Tree very prolific. Season December to February. Thought to be a Guatemalan-Mexican hybrid.

VARIETIES MOST HARDY TO COLD, SUGGESTED FOR AMATEUR GROWERS

Variety marked with the asterisk (*) is especially recommended.

Blake.—Originated at Pasadena, California, about 1903. Fruit small, slender pyriform, smooth, light green. Seed medium. Season October to December. Mexican.

Duke.—Description given above.

Fuerte.—Description given above.

Northrop.—Description given above.

***Puebla.**—Description given above.

For further information concerning varieties the reader is referred to the *Check List of Avocado Varieties* prepared by Condit,[23] the annual reports of the California Avocado Association,[24] and to other reports published therein.

[23] Condit, I. J. Check list of avocado varieties. California Avocado Assn. Ann. Rept. 1925–26:120–139. 1926.

[24] Headquarters at 4803 Everett Avenue, Los Angeles, California.

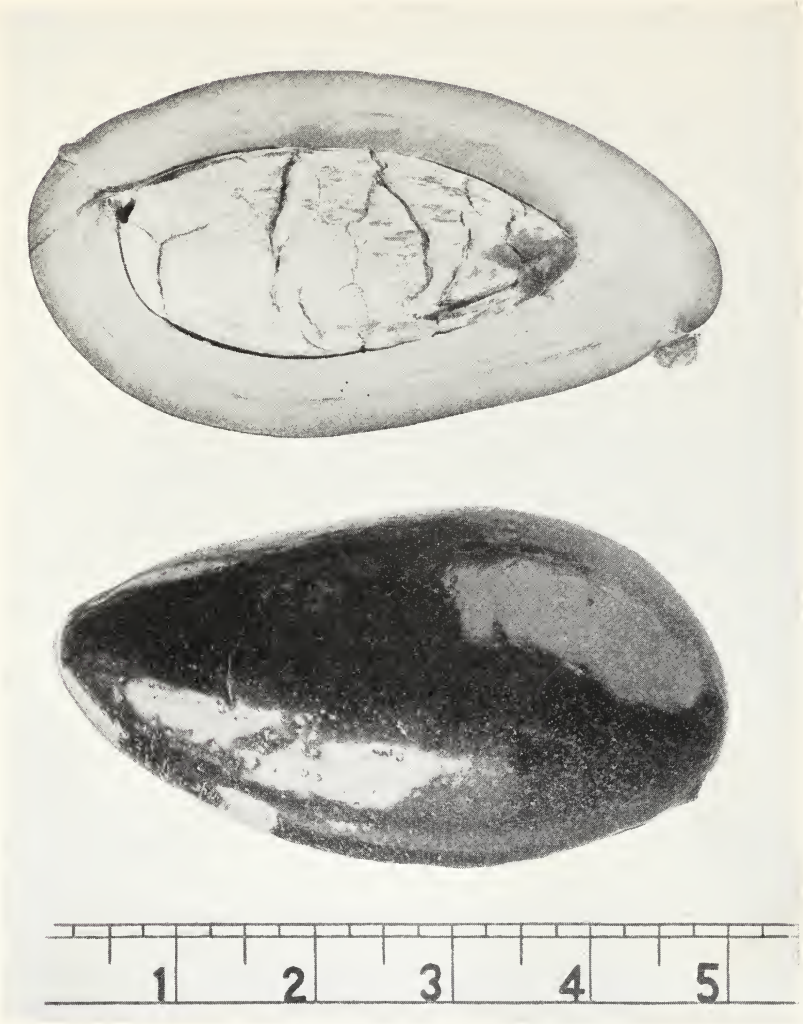


Fig. 26.—Topa Topa, a promising large-fruited Mexican variety. See text for description.

MARKET REACTIONS TO VARIETIES

For the purpose of ascertaining the market reaction to the numerous varieties of which supplies are now available in commercial quantity, which for the most part are included in the above lists, the Variety Committee of the Association recently conducted a survey of the markets. The results of this survey are exceedingly interesting and should be of inestimable value to those topworking or planting trees. The ratings given below have no relation whatever to the hardiness or growth and bearing habits of the tree, or season of maturity. They are based entirely on the reaction of the dealers as to the attractiveness and marketability of the fruit. Since some varieties now available in commercial quantity are unsatisfactory from points of view other than fruit characters, only those referred to in the lists given above will be included here. For the complete report the reader should consult the 1929 Annual Report of the Association.

Ranked as excellent: Fuerte, Nabal, Taft.
Ranked as good: Anaheim, Benik, Ishim, Linda, Puebla, Queen, Sharpless.
Ranked as fair: Dutton, Topa Topa, Worsham.
Ranked as poor: Dickinson, Mayapan, Miller.

Among the promising varieties on which the market reaction is not yet known, owing to lack of supplies, are the following: Cantel, Carlsbad, Duke, Itzamna, Kashlan, Panchoy, and Thompson.

USES OF THE FRUIT—BY-PRODUCTS

The avocado is used principally as a salad food. As its general food value becomes more appreciated it will undoubtedly find a much larger place in the diet of the American public. In addition to its common use for salads, a considerable number of methods of using the fruit have been devised by housewives and chefs, including avocado ice cream and sandwich filling. The reception which these innovations have met is indicative of the popularity the avocado will enjoy when it is placed on the market in sufficient quantity and at a price within the reach of all.

Thus far the problem of disposing of the poorer grades of fruit has not become especially pressing; most of it has been absorbed by the markets, although at prices not always satisfactory to the producers. The time is near at hand, however, when the volume of fruit will be such that in some seasons at least this problem will be exceedingly important. Anticipating this situation, for several years past studies

have been under way to determine possible and profitable outlets for the poorer grades of fruit. Among the agencies which have done work in this field are the Division of Fruit Products of the College of Agriculture and the Bureau of Chemistry of the United States Department of Agriculture. The studies of Cruess and his associates[25] have been especially comprehensive.

The most promising product developed thus far is the natural fruit pulp preserved in freezing storage. The seed and peel are removed and the pulp ground and stored in sealed containers of glass, enameled tin, or paper at a temperature of 15° F or lower. Pulp to be used for ice-cream manufacture should be sweetened with one part of sugar to three or four of pulp. The unsweetened pulp may be used as a salad base, filling for sandwiches, manufacture of mayonnaise, or as a base for milk shakes and other fountain drinks. The addition of cider vinegar, one part to five of pulp, gives a product which is very attractive as a salad base or sandwich spread. One of the principal problems connected with the storage of the pulp is the browning occasioned by oxidation. Pulp preserved by freezing storage should be used as soon after taking out of storage as possible. If the cost of the frozen pulp can be reduced to the point where it is attractive to the fountain trade this product should offer an important means for solving the problem of disposing of poor quality or surplus fruit.

Both dehydration and canning have thus far given products so unattractive as to have no value whatever. While the oil can be extracted, unless special use for it can be found, it appears to offer little promise as a profitable product.

NUTRITIVE AND DIETETIC VALUES[26]

The composition of the avocado is remarkably different from that of other fruits used in the fresh state, the closest resemblance being found in the case of the processed ripe olive. Its average protein content, 2.1 per cent, is approximately three times that of the ordinary fresh fruits on the market—the apple, pear, grape, berries, citrus fruits, banana, etc. In this constituent the olive runs slightly higher than the avocado. In minerals, represented by the ash, its average content of 1.32 per cent is between two and three times that of the common fresh fruits. On a dry-matter basis its average of 29.44 per

[25] Cruess, W. V., and Elizabeth Harrold. Investigations on the utilization of cull avocados. California Avocado Assn. Ann. Rept. **1927**:34–38, 1927.

[26] Taken largely from Jaffa, M. E., and H. Goss. Avocado culture in California. Part II. Composition and food value. California Agr. Exp. Sta. Bul. **365**:630–638. 1923.

cent is higher than that reported for any other fruit, its closest competetitor in this respect being the banana with about 25 per cent.

On the other hand, as would be expected, the carbohydrate content of the avocado, averaging about 4.5 per cent, is low as compared with this constituent in other fresh fruits, where the range is from 8 to 10 per cent up to as high as 20 per cent or more.

It is in its fat or oil content that the avocado differs most greatly from other fruits, the ripe olive alone excepted. Whereas most fruits contain little or no fat the average for the numerous determinations on the avocado is 20.6 per cent.

It is evident therefore that so far as protein, minerals, and fat are concerned the avocado stands at the head of the list, and with reference to carbohydrates contains fully 50 per cent of that found in many fresh fruits. These facts alone would warrant the conclusion that this fruit unquestionably contains nutritive values far exceeding those of other fresh fruits.

The caloric or energy values of the edible portion of the commonly used fresh fruits are low, ranging from a minimum of 175 calories to a possible maximum of 400 calories per pound. The average for the avocado as determined by Jaffa and Goss is 1,056 per pound, or two and a half times the maximum for the other fruits. The maximum, 1,376 calories per pound, corresponds to that noted for some kinds of dried fruits and is approximately 75 per cent of the energy value of the cereals and far in excess of that of lean meat.

Digestion experiments by Mattill[27] have shown that the digestion coefficient for avocado fat for man is identical to that for butterfat. While there are no reports of metabolism experiments concerning the protein and carbohydrates of the avocado, the assumption seems warranted that this fruit is as easily digested as many others whose coefficients have been determined. The availability of the fats and mineral matter are fully equal to that obtained for a mixed diet.

Santos[28] has shown that the avocado is an excellent source of vitamin B, the antineuritic vitamin. More recently Weatherby[29] reports having confirmed Santos' results on vitamin B. Weatherby, Youtz, and Watson[30] have proved the occurrence in this fruit of vitamin A, the antixerophthalmic vitamin. Studies are now under

[27] Mattill, H. A. The digestibility of the fat of the avocado. California Avocado Assn. Ann. Rept. 1916:93–95. 1917.

[28] Santos, F. O. Some plant sources of vitamins B and C. Amer. Jour. Physiology 59:310–334. 1922.

[29] Weatherby, L. Vitamin investigations of the avocado. California Avocado Assn. Ann. Rept. 1928:58–67. 1928.

[30] Weatherby, L. S., J. E. Youtz, and R. E. Watson. The vitamin A content of avocados. Jour. Home Econ. 21:360–364. 1929.

way for the purpose of ascertaining the content of vitamin C, the antiscorbutic vitamin.

The dietetic value of fruits, aside from the actual nutrients they contain, lies in their succulency, minerals, vitamins, and organic acids. Judged from all points of view, therefore, the avocado undoubtedly possesses unusually high nutritive and dietetic values. To judge from its composition, the avocado should perhaps prove to have laxative qualities of a peculiar type, possessing as it does the combination of the usual 'fruit principles,' and that of fat or oil. The laxative properties of most fruits depend upon the stimulating effects of the fiber upon the wall of the intestine and partly upon the organic acids and minerals. Oil has a tendency to soothe and to lubricate the intestine even while it acts as a mild laxative. The avocado is a natural combination of these two types of foods—as if fruit and olive oil had been chemically combined by nature. Whether or not there is any special advantage in this natural combination over that made by a proper selection of foods remains to be proved. There are no clinical data on the subject, but future experimental work may furnish some interesting results.

The fact that the native Cubans prefer this fruit to any other of their abundant supply may be due to its flavor alone, but it is more than likely that the preference has a deeper foundation and that it is the results of generations of experience or knowledge of its beneficial effects.

COSTS, YIELDS, AND RETURNS

On account of the newness of the industry, data concerning its various economic phases are both fragmentary and small in amount. While lacking the assurance afforded by larger volume they are nevertheless highly suggestive and worthy of serious consideration on the part of the prospective planter. In general they indicate higher average costs than those which obtain in the citrus industry, concerning which abundant and accurate data are available.

Costs of Establishing the Orchard.—Land suited for avocados, with a satisfactory water right, costs from $600 to $3,000 an acre, depending on location. Much, if not most, of the good avocado land possesses a high locational or residential value entirely aside from its agricultural value, and this of course enters into its cost. It appears doubtful whether the returns from avocado culture will ever justify the high capitalization required in many of the districts of high residential valuations. Undoubtedly many plantings have been established with the insuperable handicap of excessive capitalization to start with.

Costs of installing irrigation systems vary greatly with slope and topography and the type of system installed. For relatively flat land where the standard concrete pipe and irrigation stand system is used the cost may be as low as $75 to $100 an acre. For hillside land, if the overhead system is installed, the cost may reach $400 an acre.

Costs of land preparation may range from a few dollars an acre with flat land to $150 an acre for terraced hillside land. The cost of trees is high and, according to the distance of planting, may range from $150 to $300 an acre.

The period required before the trees reach commercial production is at present decidedly uncertain and highly variable. It is doubtful whether this can properly be regarded as less than five or six years; with some varieties it is considerably longer. Maintenance costs during this period may range from $40 to $75 an acre a year. In some cases these may be partially or entirely defrayed from the returns received from intercrops; in many cases intercropping is either impracticable or unprofitable.

It is evident, therefore, that the capital required to establish an avocado orchard and bring it into commercial bearing is large, often amounting to several thousand dollars an acre. Assuming that the land costs $1,200 an acre, its preparation $25, the irrigation system $100, the trees $175, and the maintenance $300 for five years, the total investment per acre at the beginning of the sixth year would be $1,800 an acre, not counting interest on the investment. This is certainly as cheaply as it can be done under what might be considered favorable conditions. In most cases it has cost much more than this. Where orchard heating is required, from $200 to $300 an acre must be added to the capital investment; if terracing or contouring are necessary, from $50 to $125 an acre; and if a permanent overhead irrigation system, from $200 to $300.

Orchard Maintenance Costs.—Costs of maintaining bearing orchards vary greatly but in general are similar to those required for citrus orchards, ranging from $200 to $400 an acre a year. The manager of one of the largest bearing orchards reports a four-year average of $406.25 an acre. Among the most variable cost items entering into maintenance costs are those for water, fertilizer, orchard heating, and picking. Thus far costs of insect pest and disease control have been small.

Cost of Production per Pound.—Few data are available on the cost of production per pound of fruit, which varies greatly from year to year, mainly on account of the marked fluctuation in yield. What

data are available[31] indicate a cost of 5 to 6 cents a pound for efficiently managed productive orchards. This is much lower than the present average for the California industry.

Marketing Costs.—Owing primarily to the relatively small yet widely fluctuating supply of fruit and the necessary expense attendant on its introduction in the market, costs of marketing are still high, averaging in the neighboring of 12 to 15 cents a pound. As the fruit becomes better known to the dealers and consumers and the volume of production increases this cost will undoubtedly be materially reduced.

Yields.—In discussing yields it should be borne in mind that as yet there are no avocado orchards of any one variety in California which may be said to have reached full-bearing age. The oldest plantings of this kind are still short of twenty years old, and there are, in fact, no commercial plantings of any kind which exceed this age. While large old individual trees exist which in some years have given phenomenal yields, it is already clear that these cannot safely be used as criteria for estimating the production from orchard plantings. The unpleasant fact is that orchard yields thus far have in general proved to be very disappointing. On the basis of the largest production to date, the season of 1928–29, considering all trees four years old and over, the average production per acre was approximately 1,000 pounds. This is manifestly much lower than a reasonable expectation from good bearing orchards, yet it serves to emphasize the comparative low-yielding habit which has thus far characterized the industry in this state. Records of yields averaging 100 pounds or more per tree in favorable seasons have been reported, yet the fact remains that for the past four-year period the largest orchard of one variety in commercial bearing in this state, 10 acres now in its seventeenth year, has averaged approximately 50 pounds per tree per year. And this orchard has received much better care than the average! In some years the average has been practically double this figure but in others much below it. Experience thus far indicates that with most of the varieties now grown, on the average in any five-year period the grower may reasonably expect two good crops, one or two fair crops, and one or two poor crops. Until the alternate habit of bearing is overcome or varieties found or developed which do not exhibit this phenomenon, it does not appear that growers can reasonably expect to obtain average yields, even on large bearing trees, in excess of 100 to 150 pounds of fruit.

Prices and Returns.—Only a few years ago when the production was small, prices of 60 cents to a dollar a pound to the producer were

[31] Tariff statement prepared and presented by the California Avocado Association and Calavo Growers of California, 1929.

not uncommon, and many growers entered the industry under the impression that prices of this kind were likely to prevail for some years, if not indefinitely. As was to be expected, however, as the production increased average price levels declined. While high prices still prevail during certain seasons of the year when supplies are low, average returns to the growers have now reached the point where they represent only a small fraction of the return of a decade or so ago. The progressive downward trend, as well as the effect of fluctuating supplies, are clearly shown in table 1.

TABLE 1

AVERAGE NET RETURN TO THE GROWER FOR PICKED AVOCADOS[32]

Season	F.o.b. price per flat (13.5 lbs.)	Net return to the grower (per lb.)
1924 (9 months)	$4.60	$0.26
1924–25	6.52	0.41
1925–26	6.05	0.33 (light crop)
1926–27	4.46	0.19 (large crop
1927–28	6.98	0.39 (light crop)
1928–29	3.50 (estimate)	0.16 (estimate) (large crop)

Obviously the growers with good crops in the light-crop years or those with fruit to market during that part of the season when supplies are light have made good returns, in some cases amounting to phenomenal profits. The great bulk of the growers, however, especially those whose orchards are just reaching bearing age, have by no means received the fabulous returns often credited to the avocado industry.

OUTLOOK—PRESENT AND FUTURE

That the avocado has come to stay as an important crop in California is now reasonably assured. With ever-increasing land values, especially in the more climatically favored portions of the state, crops and fruits yielding high gross returns per acre must be grown, and the avocado is one of these. The food value of the fruit itself and its potentially high return per acre are sufficient reasons to justify its place in California horticulture.

Regardless of the future, however, there are certain facts and conditions in this young industry which should be more clearly recognized. On account of its newness, the industry is necessarily far from

[32] Data supplied by Calavo Growers of California.

being standardized or stable with reference to either varieties or production methods and marketing procedure. Important and perhaps revolutionary changes may therefore be expected to occur before a condition of relative stability is reached. In its present stage of development avocado growing is not an undertaking for the inexperienced person of limited means. The efforts being made by some individuals and companies in this state to attract the small investor with the hope of phenomenal returns or a livelihood from an acre or less, based on the behavior of exceptional trees and the abnormal prices of some years ago, cannot be too strongly condemned. The industry cannot develop with safety on this basis.

The industry is still to a large degree to be regarded as in the experimental stage with the attendant high risks. The initial capital-investment requirements are high; maintenance and production costs are likewise high; the tree is tender and erratic in behavior; frost protection must be almost universally provided if the capital investment is to be protected. Adequate capital must be available to maintain the orchard until it comes into profitable production, and the acreage should be large enough to warrant the use of commercial orchard-management methods.

Before the industry can become stabilized, at least one important production problem must be solved: that of the erratic bearing habit of many of the best varieties. Of the marketability of some of these varieties there can be little doubt, but unfortunately some of the best of them are seriously affected with the alternate-bearing tendency. Some means of correcting this must be found or new varieties will have to be introduced or developed.

What the future holds for the industry is of course a matter of conjecture. There are, however, certain facts which will probably have some bearing upon it. There are those who believe that the unequalled food value of the fruit when it becomes widely known will be sufficient to maintain relatively high price levels. However, it seems certain that for many years to come at least, as in the case of other fruits, price levels will continue to be determined mainly by the relation between supply and demand. That production is destined to increase rapidly is clearly evident from the facts at hand. The present planted acreage in California consists of about 2,500 acres in bearing and 5,000 in nonbearing trees.[33]

[33] Tariff brief already referred to. The California Crop Report for 1928. Kaufman, E. E. (California crop report for 1928. California Dept. of Agr. Spec. Publ. 96:1–67. 1929.) reports the 1928 acreage as 1,820 bearing and 312 nonbearing with 1928 plantings of 1,371 acres. The 1929 plantings have materially exceeded those of 1928.

The California production for the past five years is shown in table 2.

TABLE 2

CALIFORNNIA AVOCADO PRODUCTION[34]

Season	Pounds
1924	259,750
1925	466,500
1926	1,249,500
1927	637,500
1928	4,005,000

It is clearly evident that within a few years the production in this state will reach ten million pounds, or more in some seasons, even though much of the recent planted acreage may never reach commercial production owing to poor choice of planting sites or lack of care.

While the Florida avocado industry has suffered severely from climatic and other vicissitudes in recent years, the production there will probably increase. The present bearing area in that state, estimated at between 500 and 600 acres, has produced more than one million pounds of fruit in a season. New plantings are now being made which, if successful, will materially increase the Florida production.

Imports of avocados have at times reached high totals, as shown in table 3.

TABLE 3

AVOCADOS IMPORTED UNDER QUARANTINE NO. 56 FOR THE YEARS 1924 TO 1927 (IN POUNDS)[35]

Country	1924	1925	1926	1927
Peru				550
Haiti	1,680			
Dominica		1,670	22,944	7,400
St. Lucia				6,620
Jamaica			4,070	18,470
Dominican Republic	3,250		3,050	23,923
Colombia		13,750	30,202	
Mexico (seeded)	28,124	56,635	54,214	104,049
Cuba	4,036,240	4,945,709	5,261,367	2,169,281
Totals	4,091,804	5,017,776	5,376,247	2,330,293

[34] Kaufman, E. E. California crop report for 1928. California Dept. of Agr. Spec. Publ. 96:1–67. 1929.

[35] Compiled by S. W. Shear, Division of Agricultural Economics, University of California. April, 1929.

It will be observed that Cuba supplies by far the greater part of the avocados imported into the United States, with Mexico second. The marked decrease in Cuban receipts in 1927 was caused by the unprecedentedly severe hurricane of September, 1926, which affected not only the crop for 1927 but also the succeeding crop. Reports indicate that the Cuban industry is now fully recovered and that the volume of fruit which could be shipped to the United States if desirable, is two or three times the largest amount ever exported in one year.

With the certainty of rapidly increasing production and the likelihood of rapidly mounting imports it seems inevitable that average price levels must continue to decline. In the opinion of those most familiar with the economic and marketing aspects of the industry it is not unreasonable to anticipate the occurrence, in the not distant future, of returns of 5 to 8 cents a pound to the grower. In this connection it should be of interest to the California avocado grower to note that the information available indicates that during the past decade the returns to the Florida growers have approximated these figures. It is certain that the Cuban growers have, on the average, received much less, for the shippers commonly purchase the fruit at a cent a pound on the trees and it often sells in our markets at 2½ to 3 cents a pound.

Moreover, while the areas adapted to avocado culture in the United States are relatively small, they still provide for the possibility of increasing the acreage manyfold. It is conservatively estimated that the potential commercial avocado area in California ranges from 30,000 acres to 40,000 acres and that in Florida the possible acreage is at least half this amount. The greater part of these areas in both states are now occupied by other crops, however, mostly the citrus fruits, a condition which will probably continue unless avocados should prove to be relatively more profitable. In the light of the facts above reported it is doubtful whether any great part of this acreage will be replaced by avocados, at least in the near future.

Production costs in Florida and Cuba are undoubtedly much lower than in California and will probably remain so. On the other hand it appears that the California growers enjoy certain advantages, which if utilized to the fullest possible degree may equalize or even outweigh the disparity in production cost. The California industry has been developed almost altogether on the basis of the Guatemalan varieties in contrast to the Florida and Cuban production, which at present consists mainly of West Indian varieties or seedlings. While individual preferences vary and are often strongly marked, experi-

ence in general indicates that the range of sizes afforded by the former group and their more pronounced and distinctive flavor constitute an important marketing advantage. In most markets the large size of most West Indian fruit is a distinct handicap. Moreover the appearance of the California fruit, owing largely to climatic conditions, is usually more attractive. While Guatemalan varieties can be, and to a certain extent are, grown in Florida, there is reason for believing that their flavor and keeping qualities are inferior to the California fruit. The availability of California supplies the year round is likewise an advantage of considerable importance.

The California avocado industry also enjoys a decided advantage in that it is organized to a much greater degree than exists elsewhere and is represented in the markets by an aggressive, efficiently managed cooperative selling agency which controls the greater part of the crop. Through the efforts of this organization standards for grades, sizes, and packages have been developed which have proved both acceptable and attractive to the trade. Much trade promotional and advertising work has been done by this agency, with the result that the California product is undoubtedly the best known and generally preferred and most highly standardized avocado on the market.

In spite of these advantages, ever-increasing, intensive competition faces the California avocado grower. And like all other young horticultural industries it may be expected to have its ups and downs before it is stabilized on a moderately profitable basis. Price levels will either continue to decline or orchard values will advance to the point where the interest on the investment will materially reduce the net returns. There is every reason for believing that within the coming decade the industry will pass through the exploitation stage and settle down to a commercial basis, when the profits will not differ materially from those of other California specialty subtropical fruits such as the late Valencia orange, lemon, summer grapefruit, and date.

In any event, the future success of the industry will depend on the employment of the same methods that have brought success to the growers of other California fruit crops, namely the production of fruit of the best possible quality at the lowest possible cost, the preparation of it for market in the most attractive manner, rigid adherence to grading and standardization, and the use of the most efficient merchandising methods.

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